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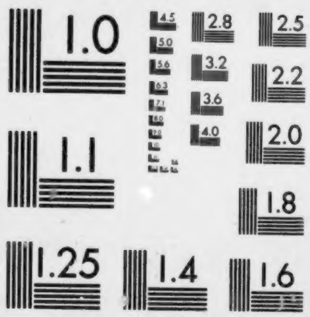
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ABSTRACT

The purpose of this study was to compare brain wave patterns produced by high and low grade point average students, while they were resting, solving problems, and subjected to stress situations. The study involved senior midshipmen at the United States Naval Academy. The high group was comprised of those whose cumulative grade point average was between 3.50 and 4.00. The low group was comprised of those whose grade point cumulative average was between 2.00 and 2.25. Instrumentation included a Grass model 79C electroencephalograph, analog/digital filters, digital clocks, digital counters, and an eight channel oscilloscope. Treatment means were evaluated using a repeated measures design and a simple analysis of variance. The following conclusions were reached: (1) There were differences in brain wave patterns, depending whether the subjects were resting, solving problems, or under stress; and (2) The data did not support the hypothesis that high and low grade point average students would have differing brain wave patterns. Several suggestions are made as to areas for future research, and implications of the study are discussed. (Author/LAA)

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A COMPARISON OF BRAIN WAVE PATTERNS OF HIGH AND LOW GRADE POINT AVERAGE STUDENTS DURING REST, PROBLEM SOLVING, AND STRESS SITUATIONS

by
Karel Montor

Dissertation submitted to the Faculty of the Graduate School
of the University of Maryland in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
1973

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To officers and civilians at the United States Naval Academy, thanks is given for the material and spiritual help provided over the years of my doctoral studies. I am indebted to my family who supported the doctoral efforts over so many years.

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CHAPTER I

INTRODUCTION

This study had two purposes. The first was to determine if brain wave production differed when college students shifted their attention from (a) resting with their eyes closed, to (b) solving of numerical and conceptual problems, to (c) being faced with stress producing situations and whether these differences were statistically significant. The second purpose was to determine whether high grade point average students produced statistically significant differences in their brain waves while resting, problem solving, and under stress, when compared to low grade point average students.

The subjects were senior midshipmen at the United States Naval Academy. The high group was comprised of those whose cumulative grade point average for their first three years at the Academy was between 3.50 and 4.00. The low group consisted of those whose cumulative grade point average for their first three years at the Academy was between 2.00 and 2.25.

SIGNIFICANCE OF PROBLEM

Through extensive research, development, and modification, educators and psychologists have been able to develop a variety of test instruments which are capable of measuring differences between high and low grade point average students. Ertl, in commenting on the sometimes invalid use of IQ tests, however, has suggested that the potential for misinterpretation of brain wave analyzed data would be less than with existing pencil and paper tests. The present study is an attempt to add to our knowledge of differences in brain wave production which can be related to differences in academic achievement. The basis of this assumption is that cellular neurological differences may be a contributor rather than a determiner of academic differences.

HYPOTHESES TO BE RESEARCHED

The first research hypothesis was that differing treatments (resting, solving problems, or under stress) would produce significantly different brain waves for all subjects. A sub-hypothesis was that differing treatments produce significantly different theta, alpha, and beta brain wave patterns for all subjects.

The second research hypothesis was that identical treatments applied to students who had high and low grade point averages would result in the production of statistically significant differences in their brain wave patterns. A sub-hypothesis was that students of high grade point average produce significantly different theta, alpha, and beta brain waves than do students of low grade point average.

The differences measured were to be related to the time in seconds that a particular brain wave (theta or alpha or beta) reached or exceeded a 10 microvolt level during a particular treatment. The differences measured were also to be related to the number of times that a

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[1] William Tracy, "Goodbye IQ, Hello EI (Ertl Index)," Phi Delta Kappan, LIV (October, 1972), 89-94.

particular brain wave reached or exceeded a 10 microvolt level during a particular treatment.

ASSUMPTIONS

The researcher accepted certain basic assumptions regarding the nature and measurement of brain wave patterns in the development and carrying out of this study:

(1) that measurements should be taken between scalp locations 01 and T3 with reference to the International Electrode Placement System (the two points respectively near the back of the head and above the ear);

(2) that measurements should be taken only when brain wave production is at or above 10 microvolts for each of the three frequency bands considered in this study, that is theta, alpha, and beta;

(3) that frequency bands of 4 to 8 Hz (theta), 8 to 13 Hz (alpha), and 13 to 30 Hz (beta) were appropriate for the study.

LIMITATIONS

The findings apply only to the particular groups studied, and generalization to all midshipmen at the United States Naval Academy and/or the general population would be premature until further verifying studies have been completed.

A single resting period and three problem solving treatments were used, each of three minutes duration. However, because two stress treatments were applied, each of one minute duration, the data recorded during these treatments were increased by a multiple of three so that equivalent data for each treatment could be compared.

The research design did not provide for varying the sequence of treatment application. The decision not to counterbalance was made to insure uniformity of treatment application and subject safety.

PROCEDURES

After the parameters and approaches of the study were determined, specifications were established for equipment configuration. The analog/digital filtering and recording system was specifically built for this study, and the latest solid state electroencephalograph was procured.

Simultaneously with the establishment of the laboratory necessary to conduct this study volunteers were obtained and tested for electroencephalographic normalcy at the Bethesda Naval Hospital. Following application of treatments to all subjects, the data was analyzed on computers at the University of Maryland and the U. S. Naval Academy.

In order that the conclusions be logically and validly applied to the data obtained, care was taken in the design of this study to consider factors relating to internal and external validity.[2] The following procedural steps were employed:

(1) All treatments were applied within a seventeen minute time frame and the subjects were not told the results of any treatment until

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[2] Donald T. Campbell and Julian C. Stanley, Handbook of Research on Teaching, ed. N. L. Gage (Chicago: Rand McNally, 1963), p. 171-246.

after all subject testing had been completed.

(2) Equipment was re-calibrated between measurements on each subject.

DEFINITIONS

To provide the reader with the researcher's frame of reference the standard terms and definitions used are presented below:

Treatments -- The recording of brain wave production measurements while the subject rests, solves algebraic problems, solves a three dimensional conceptual problem, does cumulative number adding, and is subjected to two kinds of stress-producing stimuli.

EEG or Electroencephalograph -- A high gain amplifier capable of translating electrical signals produced by the brain into graphic representations. (The EEG used was modified by the addition of analog and digital filtering circuits so that the brain waves produced by the subjects could be converted into discrete digital form.)

Theta Wave -- Those brain wave frequencies between 4 and 8 Hz (cycles per second).

Alpha Wave -- Those brain wave frequencies between 8 and 13 Hz.

Beta Wave -- Those brain wave frequencies between 13 and 30 Hz.

Muscle Artifacts -- Voltages resulting from muscular activity.

Sub-level -- A condition when none of the three brain waves produced by the subject were at or above the 10 microvolt level. (A fourth clock and separate counter tabulated the duration and extent of this state.)

ORGANIZATION OF STUDY

Chapter I provides the basic introduction to the study along with a discussion of the significance of the problem studied and a statement of the hypotheses to be researched. Included are presentations of the assumptions and limitations of the study as well as the procedures and definitions employed.

Chapter II deals with the development of brain wave measurements and brain wave analysis in educational research.

Chapter III concerns itself with the methods and procedures used, including the design of the experiment. The subjects are described along with the design of the instrumentation and testing procedures. The manner of application of treatments and the recording of data are also included in this chapter.

Chapter IV presents and analyzes the findings with respect to the three brain wave areas.

Chapter V summarizes the results of the study and suggests areas for future research.

CHAPTER II

RELATED RESEARCH

This chapter traces the development of brain wave measurement from its inception to the present. The history of relating brain waves to human behavior is less than fifty years old, and this chapter presents some of the findings of researchers who have been trying to relate neurological findings to observed behavior.

DEVELOPMENT OF BRAIN WAVE MEASUREMENT

The technique of measuring brain wave production dates back to the Nineteenth Century. "The first observations on electric potentials of the brain were reported in 1875 by Caton, who with nonpolarizable electrodes and a sensitive galvanometer, recorded currents from the exposed brains of monkeys and rabbits and described the variations of these currents with sleep and approaching death."[3] Strauss, Ostow, and Greenstein in tracing the history of the development of brain wave measuring techniques note that "Beck, in 1890, with a galvanometer, first found continuous and spontaneous changes in cerebral potentials not due to any stimulation and independent of the respiratory and cardiac rhythms."[4] On July 6, 1924, Berger made the first recording of a human electroencephalogram.[5] In 1942 Cohn employed an optomechanical instrument, the cycloscope, to study intracerebral wave patterns.[6] By 1947 Sonneman and Kennard had reported that they had been able to study by EEG analysis the temporal variability among simultaneously occurring events in the brain.[7] One of the first steps that was to lead to automatic brain wave analysis was the development in 1948 by Goodwin and Stein of a brain wave correlator which transformed the conventional EEG into square wave patterns independent of the wave form or amplitude from different brain areas.[8]

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[3] H. Strauss, M. Ostow, and L. Greenstein, Diagnostic Electroencephalography (New York: Grune & Stratton, 1952), p. 1.

In 1949 Cohn found that frequency regulation may fluctuate two and one-half hertz per second and still be within the normal range of variation,[9] while Lilly developed methods offering the possibility for both short time evaluation as well as long term averaging using display systems. These display systems "permit one to observe patterns of illumination by an array of lights over an area, corresponding to the movement of spreading peak voltages over a region of cortex."[10] Burch, in 1959, developed the forerunner of the brain wave measurement technique used in this study. This technique, known as "period analysis," views the EEG data in terms of time intervals between either base-line crossings or successive wave peaks.[11] By 1965 Darrow and Hicks illustrated the effect a small attention-getting alerting stimulus has on the EEG.[12] As of this writing, research in brain wave measurement is being aided by the use of on-line computers.[13]

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[4] ibid, p. 1.

[5] ibid, p. 2.

[6] Robert Cohn, "A Cycloscopic Study of the Human Electroencephalogram," Journal of General Physiology, 25 (March, 1942), 517-522.

[7] H. Sonneman and M. A. Kennard, "An Interphase Analyzer of the Electroencephalogram," Science, 105 (April, 1947), 437-438.

[8] C. W. Goodwin and S. N. Stein, "A Brain Wave Correlator," Science, 108 (November, 1948), 507.

[9] Robert Cohn, Clinical Electroencephalography (New York: McGraw-Hill Book Company, 1949), p. 20.

EEG RECORDING TECHNIQUES

Milnarich points out that to record brain waves correctly it is necessary to maintain low electrical resistance between the scalp and electrodes, in order to provide a clear pathway from the brain to the recording instrument.[14] Milnarich also notes that recording artifacts may interfere with brain wave analysis, and identifies these artifacts as potentials which are recorded on the electroencephalogram but are derived from a source outside the brain. In addition to poor electrode contact, other sources of artifacts, are (1) nonsymmetrical electrode placement, (2) outside electrical interference, (3) defects in apparatus, (4) physiologic potentials arising from sources other than the brain, and (5) uncooperative patients.[15]

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[10] J. C. Lilly, "A Method of Recording the Moving Electrical Potential Gradient in the Brain: A 25-Channel Potential Field Recorder," in Proceedings Second Annual Joint IRE-AIEE Conference on Electronic Instrumentation in Nucleonics and Medicine (New York, 1949), p. 37.

[11] N. R. Burch, "Automatic Analysis of the Electroencephalogram: A Review and Classification of Systems," Electroencephalography and Clinical Neurophysiology, 11 (November, 1959), 827-834.

[12] C. W. Darrow and R. Hicks, "Interarea EEG Phase Relationships Following Sensory and Ideational Stimuli," Psychophysiology, 1 (April, 1965), 337-346.

[13] Peter J. Lang, "The On-Line Computer in Behavior Therapy Research," American Psychologist, 24 (March, 1969), 236-239.

[14] Rhoda Feinstein Milnarich, A Manual for EEG Technicians (Boston: Little, Brown and Company, 1958), p. 63.

Strauss, Ostow, and Greenstein stress the importance of the subject being relaxed and they note that "apprehensiveness, emotional stress or excitement sharply depress the amount of alpha activity which is usually replaced by low voltage random frequency activity or by fairly distinct fast activity."[16] Milnarich also points out that "without the cooperation of the patient, an artifact-free record cannot be obtained."[17]

RELATING BRAIN WAVES TO HUMAN BEHAVIOR

This section will review efforts of selected researchers to establish a relationship between brain waves and human behavior. In 1940 Knott found that the primary difficulty in relating brain waves to human behavior had to do with (1) records not being taken under conditions involving intellectual behavior, and (2) that while alpha activity can be looked at fairly carefully, that wasn't true of the entire EEG record.[18]

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[15] ibid, p. 69.

[16] op.cit., p. 25.

[17] op.cit., p. 42

While progress has been made over the years in relating EEG recordings to human behavior, the analysis of brain waves has not been without disagreement respecting the significance of the research findings. The remainder of this section will place in chronological perspective the doubts as well as the accomplishments claimed.

EEG record analysis had only been in existence a mere fifteen years when Lindsley, in 1944, indicated that there was little chance that a high degree of relationships would be found between EEG recordings and intelligence.[19] Nosal, reporting on the research of Schwab, noted that as of 1950 it had been found that increments in slow wave activity were present during periods of mental effort.[20] Contradictory interpretations of results achieved are pointed out by Nosal relative to the work of Ostow who maintained that, as of 1950, a relationship had not yet been found between EEG records and intelligence.[21]

In 1952, on the other hand, MacKay and McCulloch theorized that information is transmitted as a spike interval code.[22] (As previously reported on page nine of this chapter, in 1959 Burch developed a means of measuring these spikes.)

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[18] John R. Knott, "The Physiological Correlates of Intelligence," in NSSE Thirty-Ninth Yearbook, Part 1: Intelligence: Its Nature and Nurture (Bloomington: Public School Publishers, 1940), Chapter 4.

[19] D. B. Lindsley, "Electroencephalography," in Personality and Behavior Disorders, ed. J. McV. Hunt (New York: Ronald Press, 1944), pp. 1033-1103.

[20] Walter S. Nosal, A Primer for Counseling the College Male (Dubuque: Wm. C. Brown Book Company, 1968), p. 133.

[21] ibid, p. 310.

A 1956 analysis by Ellingson indicated his belief that little had been accomplished with respect to finding correlations between EEG records and intelligence since the 1944 Lindsley review.[23] Yet a year later (1957), Mundy-Castle completed a study which indicates that new knowledge in the field was being gained:

> Our first finding was confirmation of the hypothesis that alpha frequency would be significantly correlated with Vocabulary. It was also significantly correlated with Verbal IQ, Practical IQ, and General IQ. The relevant conclusion for the present context is that the amount of alpha rhythm present in an EEG is in part related to the extent to which visual imagery is used during thought, and that persons who think predominately in visual images tend to possess "minus" type (low voltage, low index) alpha rhythms, whereas those who think predominately by verbal-motor imagery tend to possess "persistent" (medium to high voltage, high index) alpha rhythms.[24]

A major analysis of past research, by Vogel and Broverman in 1964, of the relationship between EEG and test intelligence concluded that (1) "the bulk of the studies with feebleminded subjects, children, institutionalized geriatric subjects, and brain-injured adults have reported a significant EEG-test intelligence relationship," and (2)

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[22] D. M. MacKay and W. S. McCulloch, "The Limiting Information Capacity of a Neuronal Link," Bulletin of Mathematical Biophysics, 14 (June, 1952), 127-135.

[23] R. J. Ellingson, "Brain Waves and Problems in Psychology," Psychological Bulletin, 53 (January, 1956), 1-34.

[24] From Nosal, op.cit., p. 131.

"investigators who have studied normal adults have not found significant relationships between test intelligence and EEG tracings;" however, (3) "in every case in which test intelligence has been found to be related to EEG frequencies, low intelligence was associated with slow alpha frequencies and the presence of the slower EEG rhythms (delta and theta). Conversely, higher levels of intelligence were found associated with the fast alpha frequencies and an absence of the slow delta and theta rhythms."[25]

Ellingson in his 1966 review of the Vogel and Broverman report agreed that "the weight of available evidence suggests that there is no relationship in normal adults"[26] between brain waves and intelligence. Ellingson did, however, disagree with another of their conclusions and he stated his belief that "the evidence concerning relationships between normal brainwave phenomena and intelligence in children and in the mentally retarded is contradictory and inconclusive."[27]

Ellingson further "confesses to a continuing pessimism about finding significant and important relationships between EEG phenomena and complex behavioral processes."[28] He further indicates that "if relationships between complex behavior and brain electrical activity are to be found it is more likely that they will be found by recording brain electrical activity during S-R sequences, than during rest and relaxation."[29] On their part Vogel and Broverman, commenting on Ellingson's review of their 1964 paper, conclude that Ellingson's commentary is based essentially upon mistakes of fact and faulty assessment of the data.[30]

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[25] William Vogel and Donald M. Broverman, "Relationship Between EEG and Test Intelligence: A Critical Review," Psychological Bulletin, 62 (August, 1964), 132-144.

[26] Robert J. Ellingson, "Relationship Between EEG and Test Intelligence: A Commentary," Psychological Bulletin, 65 (February, 1966), 96.

[27] ibid, p. 96.

[28] ibid, p. 96.

In 1965, Sutton, Braren, Zubin, and John reported that "components of the AEP (average evoked potential) are most sensitive to changes in stimulus parameters involving decision making."[31] (This supports the theory reported on page eleven of this chapter, by MacKay and McCulloch, that "information is transmitted as a spike interval code.") The 1967 findings of Roy, Herrington, and Sutton "suggest that the waveform of evoked responses is not determined solely by the set of peripheral receptors which is stimulated but it also reflects the perceptual content of the stimulus."[32]

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[29] *ibid*, p. 96.

[30] William Vogel and Donald M. Broverman, "A Reply to "Relationship Between EEG and Test Intelligence: A Commentary," *Psychological Bulletin*, 65 (February, 1966), 99.

[31] S. Sutton, M. Braren, J. Zubin, and E. R. John, "Evoked Potential Correlates of Stimulus Uncertainty," *Science*, 150 (November, 1965), 1187-1188.

[32] E. Roy, R. N. Herrington, and Samuel Sutton, "Effects of Visual Form on the Evoked Response," *Science*, 155 (March, 1967), 1439.

From the mid-1960's to this time, the preponderance of evidence suggests that correlated relationships have been found between EEG records and human behavior. One exception to this, is a report by Nosal in 1968 in which he reports finding no significant differences between college student "leaders" and "underachievers" with respect to their alpha production.[33] Since the finding did not fully parallel the results of this study, Dr. Nosal was contacted by phone during October 1972 and the procedures used during the two studies were compared. The essential methodological difference had to do with the measurement of alpha production in the Nosal study being by "eye," while the measurements taken in this study were generated by analog/digital filter analysis. An "eye" analysis of the EEG records in this study by an experienced neurologist also failed to establish the significant differences which can, in fact, be found by analog/digital filter analysis as was done in this research.

In 1968 Bennett reported that a correlation coefficient of .593 was found between the Wechsler adult intelligence scale and the dominant brain wave frequency of the individual, with dominant frequency increasing with IQ. He did note that "a correlation of unity with an IQ test could not be expected for this type of test, as the IQ test is intended to measure all aspects of intelligence, including memory and environmental effects, whereas this work measures only the electrical characteristics of the visual pathway."[34]

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[33] op.cit., p. 175.

Pribram has observed that "changes in EEG frequency relate more to the balance between cellular synchrony and desynchrony than to the specific information content of a signal. If recorded with adquate resolution, they may indicate where the action is, but not what the action is all about."[35] Pribram further comments that "the most reliable sign of active neuronal processing of sensory information is differentiation and diversification of cellular firing patterns, as expressed by desynchronization of the EEG."[36] Confirming the findings of Sutton, Braren, Zubin, and John discussed on page fourteen of this chapter Pribram observes that "in continued problem solving behavior, increasingly complex patterns of neural events occur."[37]

Ertl has found correlations ranging from 0.30 to 0.50 between IQ test scores and parameters of the visual evoked potential which he reports in a 1969 study with a sample of 300 children whose mean age was 124 months with a range from 86 to 185 months.[38] In regard to these findings, the words of Mundy-Castle in a 1958 article seem appropriate. He points to the importance of using correct statistical procedures and observes, with respect to past studies where differences in results were found with reference to psychological correlates of EEG variability, that these differences may well have been partially due to sampling influences.[39]

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[34] W. F. Bennett, "Human Perception: a Network Theory Approach," Nature, 220 (December, 1968), 1148.

[35] K. H. Pribram, Brain and Behaviour 2 - Perception and Action (Baltimore: Penguin Books Inc., 1969), p. 63.

[36] ibid, p. 62

[37] K. H. Pribram, Brain and Behaviour 4 - Adaptation (Baltimore: Penguin Books Inc., 1969), p. 167.

[38] J. P. Ertl, "Evoked Potentials, Neural Efficiency, and IQ," in Biocybernetics of the Central Nervous System, ed. Lorne D. Proctor (Boston: Little, Brown and Company, 1969), p. 427.

In 1969 Ertl reported that "the AEP's of the high IQ subjects are more complex, characterized by high frequency components in the first 100 milliseconds which are not observed in the AEP's of the low IQ subjects. The ten high IQ subjects had a mean E3 (third sequential peak) latency of eighty-eight milliseconds while the low IQ subjects had a mean E3 latency of 194 milliseconds."[40]

In 1971 Ertl indicated the complexity of brain wave analysis he felt would be necessary to achieve meaningful results:

> Components of the AEP correspond to neural events in the processing of information in the brain; the latency of these components is very stable but their amplitude and spectral characteristics are not. Any analysis which depends on average characteristics of the AEP over an interval of time may be hard to relate to human intelligence. Analyses which are based on ratios, relative to component amplitudes, peak latencies, the first and second derivatives of the AEP, and so forth, seem more promising.[41]

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[39] A. C. Mundy-Castle, "Electrophysiological Correlates of Intelligence," Journal of Personality, 26 (March, 1958), 184-199.

[40] John P. Ertl and Edward W. P. Schafer, "Brain Response Correlates of Psychometric Intelligence," Nature, 223 (July, 1969), 422.

[41] John P. Ertl, "Fourier Analysis of Evoked Potentials and Human Intelligence," Nature, 230 (April, 1971), 526.

SUMMARY

This chapter has reviewed the history of the development of brain wave measurements from its inception to the present use of computers, as well as the efforts to relate brain wave measurements to human behavior. Although the literature search conducted as part of this study did not find reports relating EEG data to achievement, it is known that such studies are being planned by the Langley Porter Neuropsychiatric Research Institute. Though it is evident at this writing that researchers have decades and centuries of work ahead of them, enough has been learned already to justify further efforts.

We do know how to detect the existence of electrochemical activity in the brain as well as how to classify and recognize some of its more gross components. Scientific advances in wave analysis in general have allowed application of known theory to brain wave measurement to the point that today, using a super-cooled magnetometer in a shielded environment, it is possible to detect brain wave activity without electrical contact with the scalp.

A continuing limiting factor with respect to research in this area will be the cost of equipment required to do brain wave measurement. Another hindrance is the extended periods of time required to perform both the tests and subsequent evaluations of data acquired. Despite the limitations, the increasing effort in the field of brain wave research suggests that progress in the future will be swifter than it has been in the past.

CHAPTER III

METHODS AND PROCEDURES

This experiment was designed to test the hypotheses that: (1) brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress; and (2) that high and low grade point average students would have differing brain wave patterns. The experiment required (1) the identification of students to be evaluated, (2) the development of instruments to measure the data to be analyzed, (3) the establishment of testing procedures, (4) the determination of the form that treatments should take, and (5) the recording and analysis of data.

This chapter describes the general design of the experiment, contains a description of the procedures followed in accomplishing the tasks enumerated above, includes a description of the subjects used in the experiment, and describes the gathering of the data and the procedures used in analyzing the data.

DESIGN OF THE EXPERIMENT

After establishing the basic research hypotheses, it was determined that objective measurements and analyses would be facilitated by insuring that all data to be observed and analyzed were of digital form. The next step was to determine what types of treatments could lead to the generation of data suitable for hypotheses testing.

After treatments were determined, equipment was designed and procured that had as its end product easily read digital results. A neurologist evaluated volunteer subjects for neurological normalcy, and treatment application was performed during November, 1971. The final step was the computer analysis of brain wave generated data in accordance with the treatment by Winer as described in his "Multifactor Experiments Having Repeated Measures on the same Element."[42]

DESCRIPTION OF SUBJECTS

All senior midshipmen at the United States Naval Academy whose grade point average for the first three years was either between 3.50 and 4.00 or between 2.00 and 2.25 were identified. Further differences between the two groups are presented below in Table 1 (extracted from Appendix C).

Table I

DIFFERENCES BETWEEN HIGH AND LOW GROUPS

College Board	Mean		Std. Dev.			
Examination Area	High	Low	High	Low	F	
Aptitude-Verbal	634.3	566.5	75.4	48.0	13.8	$p < .01$
Aptitude-Math	697.6	633.3	47.4	67.4	14.6	$p < .01$
Achievement-English Comp.	611.1	556.5	72.7	61.0	7.9	$p < .01$
Achievement-Math	727.2	620.0	58.0	54.9	43.3	$p < .01$
Rank in HS Class	650.0	508.1	96.4	78.2	31.4	$p < .01$

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[42] B. J. Winer, Statistical Principles in Experimental Design (New York: McGraw-Hill Book Company, 1962), Chapter 7, pp. 298-312.

In accordance with standard procedures efforts were made to secure volunteers without undue pressure exerted on them to participate. Of the fifty-four men identified in the high group, twenty-eight volunteered, and twenty-five of these were determined to be free of muscle artifacts. Of the 149 men identified in the low group, twenty-nine were accepted as volunteers and twenty-five of these were determined to be free of muscle artifacts.

All testing was accomplished during the evening hours in an attempt to reduce the differences in EEG rhythms that would be due solely to the testing of individuals at various times during the twenty-four hour day.[43] All data from these tests appear in Appendix B.

INSTRUMENTATION

The entire instrumentation, with the exception of the sub-level circuitry, is graphically presented in Figure No. 1 on page 22.

The following frequency ranges were established in measuring the dependent variable. Recording was limited to brain wave production at or greater than 10 microvolts: theta 4 to 8 Hz, alpha 8 to 13 Hz, and beta 13 to 30 Hz. The EEG measurements were taken from 01 to T3, based on the International Electrode Placement System. Filters were used to measure simultaneously all three theta-alpha-beta brain wave states. Inter-electrode resistance between 01 and T3 was below 10,000 ohms for all subjects to avoid contamination from spurious artifacts.

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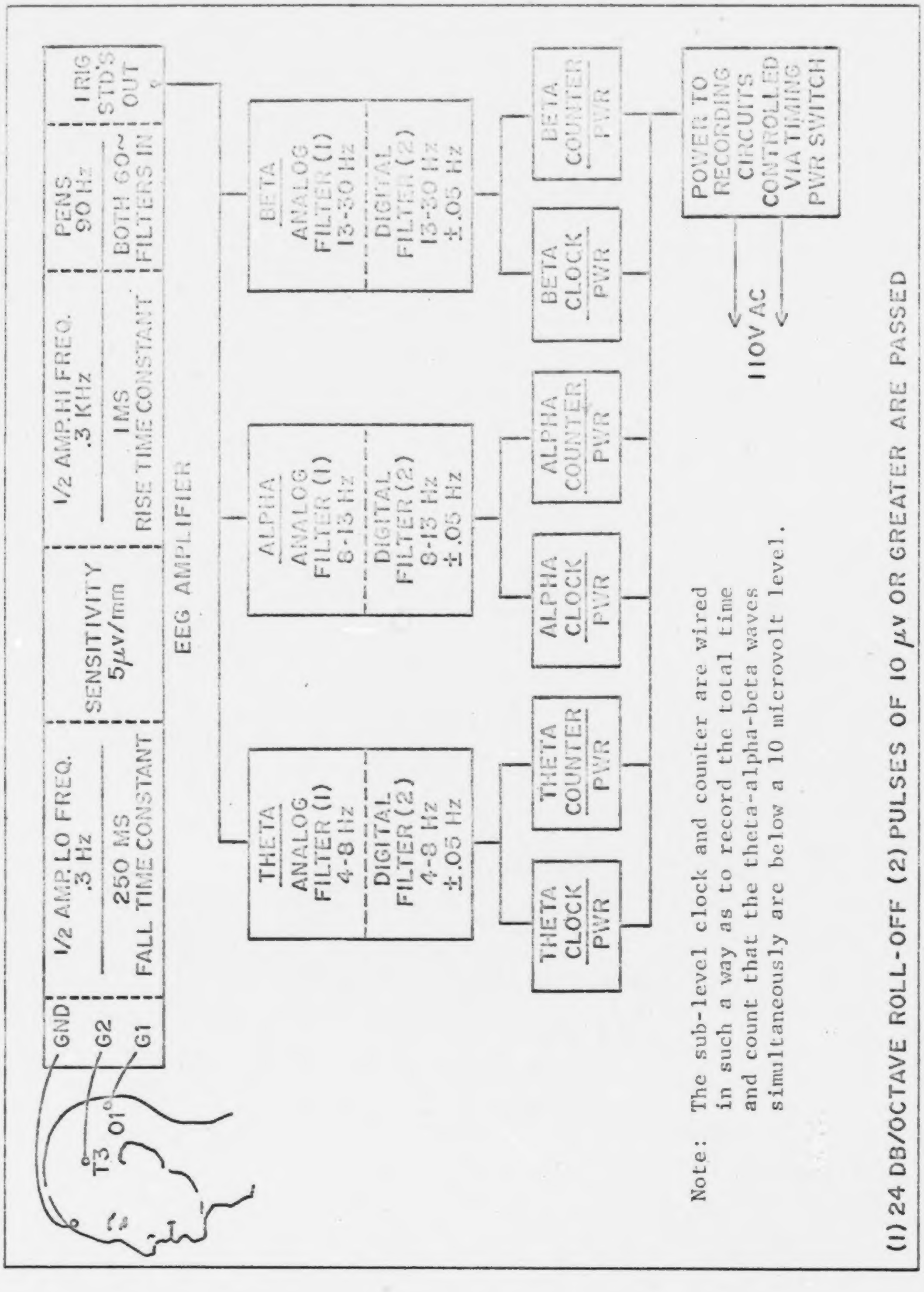
[43] Gay Gaer Luce, Biological Rhythms in Human and Animal Physiology (New York: Dover Publications, 1971), p. 57.


GND
G2
G1
T3
O1
1/2 AMP. LO FREQ.
.3 Hz
250 MS
FALL TIME CONSTANT
SENSITIVITY
5µv/mm
1/2 AMP. HI FREQ.
.3 KHz
1MS
RISE TIME CONSTANT
PENS
90 Hz
BOTH 60~
FILTERS IN
IRIG
STD'S
OUT
EEG AMPLIFIER
THETA
ANALOG
FILTER (1)
4-8 Hz
DIGITAL
FILTER (2)
4-8 Hz
±.05 Hz
ALPHA
ANALOG
FILTER (1)
8-13 Hz
DIGITAL
FILTER (2)
8-13 Hz
±.05 Hz
BETA
ANALOG
FILTER (1)
13-30 Hz
DIGITAL
FILTER (2)
13-30 Hz
±.05 Hz
THETA
CLOCK
PWR
THETA
COUNTER
PWR
ALPHA
CLOCK
PWR
ALPHA
COUNTER
PWR
BETA
CLOCK
PWR
BETA
COUNTER
PWR
POWER TO
RECORDING
CIRCUITS
CONTROLLED
VIA TIMING
PWR SWITCH
110V AC

Note: The sub-level clock and counter are wired in such a way as to record the total time and count that the theta-alpha-beta waves simultaneously are below a 10 microvolt level.

(1) 24 DB/OCTAVE ROLL-OFF (2) PULSES OF 10 µv OR GREATER ARE PASSED

Fig. 1 Equipment Configuration

One channel of a model 79C Grass electroencephalograph was used to pick up the brain wave signals. Cl was attached to 01, G2 was attached to T3, and a ground wire was placed in the middle of the forehead to minimize sixty cycle current effects. The brain wave signals were then fed into a filtering system (see Figure 1) which first used analog filters to establish the general range of theta (4 to 8 Hz), alpha (8 to 13 Hz), and beta (13 to 30 Hz). These signals were next fed into individual digital filters for each channel, so that subsequent outputs were known to lie within limits accurate to plus or minus .05 Hz. The filtering system was adjusted in such a way that only those theta and/or alpha and/or beta brain wave signals at or higher than 10 microvolts (10 uv) would be passed. Thus, all measurements noted in this study should be understood to be with reference to a 10 uv cut-off level, with theta-alpha-beta readings being at or above that level.

When a theta-alpha-beta signal was at or above the 10 uv level a relay closed and upon this action a digital clock recorded the length of this period to within one-hundreth of a second. In parallel with this clock was a counter that recorded the initial closing of the relay. At the end of a treatment it was possible to know and record for each of the three brain wave states how many total seconds the wave had been at or above the 10 uv level, and also how many times the signal went above and below the 10 uv level.

In addition, a fourth recording feature was added and it operated through the relays recording the other three brain wave changes. When all three waves were simultaneously below the 10 uv level a fourth relay was closed and it in turn operated both a clock and a counter. These are referred to in this report as sub-level readings.

TESTING PROCEDURES

Upon arrival at the brain wave research laboratory each subject had explained to him what directions he was expected to follow. Using procedures recommended by the EEG manufacturer electrodes were attached and inter-electrode resistance checked to insure that impedance was less than 10,000 ohms. The subject was advised that questions they might have during the experiment would be answered at the end of the testing period. The subjects were read all further instructions in order to maintain uniformity.

During treatments all wave forms were monitored on an oscilloscope to detect muscle artifacts should they be present and thus permit invalidating a subjects record. At the end of each treatment applied to each subject, the digital clocks and counters were read and the data recorded. The equipment was then zeroed for the next treatment.

In answer to the question most often asked - "How did I do?" - the subjects were told that this was a group experiment and it was not possible to evaluate the data on any one subject until all data for all subjects had been gathered and analyzed. Each subject was thanked for his participation and, after he left, an equipment calibration check was run to insure that the equipment was still in calibration and ready for the next subject.

The actual treatments were fourteen minutes in length and the total time from start of the first treatment to completion of the last was seventeen minutes. The total time allowed for greeting the subject, hooking him up, application of treatments, questions and answers, and washing him off was fifty minutes. Five additional minutes were scheduled for equipment calibration, and five minutes provided for the researcher to rest prior to the next subject's arrival.

APPLICATION OF TREATMENTS

Resting. Subjects were seated in a reclining chair and asked to remain quiet, with their eyes closed. Treatment length was three minutes.

Mathematics Problem. The subject was disconnected from the EEG and then shifted from the reclining chair to a desk-chair and then re-connected to the EEG. Problems presented to the subject for solution follow:

1. If a car leaves Annapolis at 1545 heading for New York City at an average rate of 57 miles per hour, how far from its destination will it meet a car that left New York City the same day at 1515 that is heading for Annapolis at an average rate of 43 miles per hour. Assume that the distance between the two cities is 287 miles.

2. If it takes 987 men 1435 days to build an aircraft carrier-how long will it take to build the same carrier if we are able to replace the slowest 17% of the men with workers who can accomplish twice as much per unit hour worked. Assume 253 working days per year and 8½ hours per working day.

3. A ship leaves Baltimore harbor at 0350 heading for San Diego-how far will it have gone after 242 hours assuming that it goes around the tip of South America and starts out at an average speed of 23 knots and increases that by 6% per day.

Treatment length was three minutes.

Conceptual Problem. The subject remained on the desk-chair. The working papers and writing instrument used in conjunction with the previous treatment were taken away and in their place was substituted the pyramid puzzle illustrated in Figure 2 below.

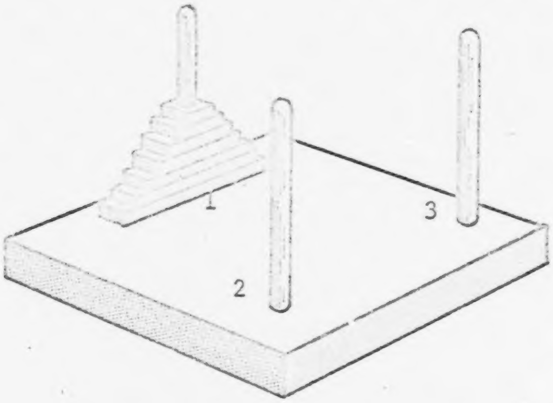


Fig. 2 Conceptualization Equipment

Subjects were instructed to try and accomplish the transfer of the pile of pieces from the number 1 peg to either of the other without moving more than one piece at a time and never putting a larger piece on a smaller one. They were advised that they could move the pieces back and forth on all three pegs as often as they wanted. The objective was to re-build the pyramid on either the number 2 or number 3 peg. Treatment length was three minutes.

Cumulative Number Adding Problem. The subject remained at the desk-chair. Instructions were given to the subject to add in his mind, "without announcing the results, 1 plus 2 which gives 3." His next operation was to "then add 3 to this total giving 6; then add 4 to that total giving 10; then add 5 to that total giving 15, and so on until told to stop." Treatment length was three minutes.

Color Stress. The subject remained at the desk-chair, and was shown a card on which were printed the names of various colors. The ink used to print each word was in a different color than that spelled by the letters of the word. For example, blue was written in green ink. The subject was asked to say out loud the color of the ink in which each word was printed. Treatment length was one minute.

Syringe Stress. The subject remained at the desk-chair. During the one minute duration of this treatment, the researcher (1) tied a restrictor around the arm of the subject, (2) cleared the air from a syringe, (3) cleaned the arm with alcohol, and (4) brought the syringe up to the subject's arm. The one minute period ended when the needle was approximately a half a centimeter away from the subject's skin.

At this point the subject was told that the experiment was over for him and that he could ask questions. Electrodes were removed after all questions had been answered.

RECORDING OF DATA

At the end of each treatment, the digital data appearing on the clocks and counters were recorded on prepared data sheets. Key punching of data was done after all subjects had been tested. Simple ANOVA analyses were performed on the computer at the United States Naval Academy. A repeated measures design was run by the Computer Science

Center at the University of Maryland in the spring of 1972.

SUMMARY

This chapter has reviewed the general design of the experiment from (1) the initial decision to procure equipment which would have easily read digital clocks and counters, through (2) determination of treatments to be used, to (3) the selection of subjects. Also included is the instrumentation configuration, testing procedures, application of treatments to subjects, and the recording of data.

Because electrical and mechanical interface characteristics were thoroughly developed before any equipment was ordered or built, the construction and assembly of the brain wave research laboratory was accomplished without significant difficulty.

The pre-evaluation of subjects for muscle artifacts proved necessary since close to 11% of the volunteers generated signals which would have interfered with the collection of uncontaminated brain wave signals.

The importance of preliminary practice in application of treatments was emphasized so that the results obtained would not be biased by the researcher's shifting procedures from one subject to the next.

Future experimenters would probably benefit by tape recording the brain wave signals for subsequent data reduction, thus permitting a smooth transition from one treatment to the next without the necessity of transcribing the results after each treatment.

CHAPTER IV

PRESENTATION AND ANALYSIS OF FINDINGS

This investigation was designed to test the hypotheses that brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress. Collaterally, it was hypothesized that high and low grade point average students would have differing brain wave patterns.

Brain wave measures were obtained for each of fifty subjects, twenty-five proven high achievers and twenty-five established as lower achievers, by administering to each of the subjects at individual times the following treatments in the same sequence.

1. Resting

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe

Appropriate F statistics were computed to permit estimation of the statistical significance of the difference between means. A two dimensional repeated measures design with repetition on the A dimension only, following a Lindquist Type I design, was the approach taken for analysis of brain wave measures. This design enabled a comparison of means, both those between high and low achievers as well as among treatment means. The assumption of homogeneity of covariance was tested and supported. The assumption of homogeneity of equicovariance was tested and not supported, resulting in an adjustment in the calculation of the F statistic relating variability among the means of the six treatments, and significance of interaction relative to the difference between the variabilities within high and low.

Because the assumption of homogeneity of equicovariance was not supported, a simple analysis of variance was calculated comparing means among subjects for each treatment. Appendix C provides a summary of all simple ANOVA calculations that compared the means of highs against lows for all treatments.

During each treatment, brain wave activity in the three ranges - theta (4 to 8 Hz), alpha (8 to 13 Hz), and beta (13 to 30 Hz) - were recorded when the brain wave signals reached or exceeded 10 microvolts in amplitude. The number of times during each treatment that the brain wave signals were at or above the 10 uv level were recorded on digital counters. The cumulative length of time to the nearest one-hundreth of a second that the brain wave signals were at 10 uv or more during each treatment was also recorded. Appendix A, in association with Appendix B, identifies the time and count data recorded during this study for all three theta-alpha-beta brain wave measurements.

DATA RELATED TO THETA BRAIN WAVE MEASUREMENTS

The theta time mean scores and their associated standard deviations for the six treatments are presented in Table II on page 31. The display of the mean figures to two places and standard deviations to one in this and subsequent presentations is done to simplify the task of reading the table.

Table II

THETA TIME MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cumnum Prob	Color Stress	Syringe Stress	Total
High	Mean	103.56	55.98	69.48	52.17	55.35	47.79	64.05
	S.D.	29.5	21.8	17.9	23.6	20.7	19.8	29.5
Low	Mean	87.46	57.86	73.88	56.38	65.31	52.14	65.50
	S.D.	40.6	20.4	19.2	31.1	25.8	21.9	30.1
Total	Mean	95.51	56.92	71.68	54.27	60.33	49.97	
	S.D.	36.8	21.4	18.9	28.0	24.0	21.3	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table III on page 32. Included in this table is a graphic representation of the mean score values.

TABLE III

THETA TIME SCHEFFÉ ANALYSIS

S indicates $p < .05$

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

					6
				5	
			4		
		3	S		S
	2	S			
1	S	S	S	S	S

Treatment

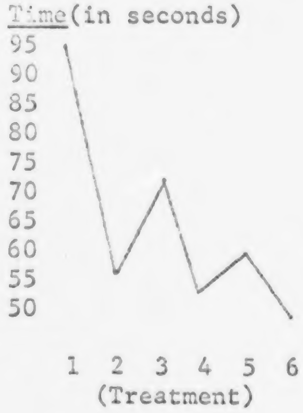
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the theta clock appears in Table IV on page 33. The Within Subjects F statistic of 39.22 indicates a significance at the .05 level with respect to variability among the means of the six treatments. This supports the hypothesis, with relation to theta time, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress." A simple ANOVA comparing high and low groups for each treatment condition resulted in no significant differences.

TABLE IV

THETA TIME REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	159.37	159.37	.07	
Subjects(s)	48	103849.55	2163.53		
Within Subjects					
A	5	70164.69	14032.94	39.22	$p < .05$
AB	5	5063.36	1012.67	2.83	
AS	240	85862.22	357.76		
Total	299	265099.19			

The theta count mean scores and their associated standard deviations for the six treatments are shown in Table V below.

TABLE V

THETA COUNT MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cum-num Prob	Color Stress	Syringe Stress	Total
High	Mean	211.60	165.00	190.64	153.08	165.72	144.48	171.75
	S.D.	35.2	44.8	23.9	47.6	40.5	50.7	47.4
Low	Mean	185.48	168.36	195.28	156.36	177.84	151.68	172.50
	S.D.	67.6	36.7	25.8	62.2	39.3	46.5	51.1
Total	Mean	198.54	166.68	192.96	154.72	171.80	148.08	
	S.D.	56.0	41.4	25.2	56.0	40.8	49.2	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table VI on page 34. Included in this table is a graphic representation of the mean score values.

TABLE VI

THETA COUNT SCHEFFÉ ANALYSIS

S indicates $p < .05$

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

					6
				5	
			4		
		3	S		
	2	S			
1	S		S	S	S

Treatment

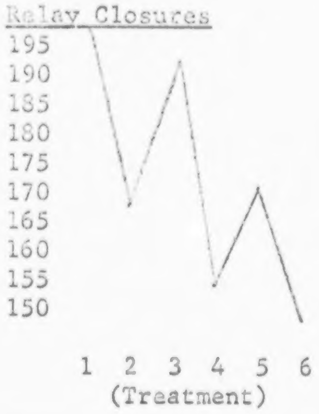
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the theta counter can be found in Table VII on page 35. The Within Subjects F statistic of 17.86 indicates significance at the .05 level with respect to variability among the means of the six treatments. This further supports the hypothesis, with relation to theta count, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress." A simple ANOVA comparing high and low groups for each treatment condition resulted in no significant differences.

TABLE VII

THETA COUNT REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	41.75	41.75	.01	
Subjects(s)	48	336521.75	7010.87		
Within Subjects					
A	5	102135.62	20427.12	17.86	$p < .05$
AB	5	11515.12	2303.02	2.01	
AS	240	274441.00	1143.50		
Total	299	724655.25			

DATA RELATED TO ALPHA BRAIN WAVE MEASUREMENTS

The alpha time mean scores and their associated standard deviations for the six treatments are presented in Table VIII below.

TABLE VIII

ALPHA TIME MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cumnum Prob	Color Stress	Syringe Stress	Total
High	Mean	160.20	121.46	127.21	125.50	117.03	113.18	127.43
	S.D.	13.9	17.6	12.1	23.6	21.0	21.0	24.3
Low	Mean	141.32	120.80	124.37	117.55	124.29	113.67	123.67
	S.D.	33.3	20.3	19.4	32.3	20.7	24.9	27.3
Total	Mean	150.76	121.13	125.79	121.53	120.66	113.42	
	S.D.	27.5	19.2	16.4	28.9	21.3	23.3	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table IX below. Included in this table is a graphic representation of the mean score values.

TABLE IX

ALPHA TIME SCHEFFÉ ANALYSIS

S indicates $p < .05$

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

	2	3	4	5	6
3					S
1	S	S	S	S	S

Treatment

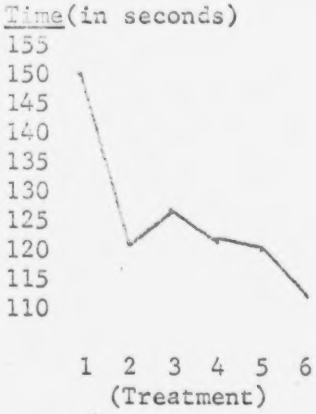
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the alpha clock appears in Table X on page 37. The Within Subjects F statistic of 31.40 indicates significance at the .05 level with respect to variability among the means of the six treatments. This further supports the hypothesis, with relation to alpha time, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

A simple ANOVA comparing high and low groups for each treatment condition resulted in a significant F statistic for the resting treatment of 6.6 which is significant at the .025 level, and is shown in Appendix C. A simple ANOVA comparing high and low groups for each of the other five treatment conditions resulted in no significant differences.

TABLE X

ALPHA TIME REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	1068.06	1068.06	.59	
Subjects(s)	48	87520.25	1823.34		
Within Subjects					
A	5	42127.25	8425.45	31.40	$p < .05$
AB	5	4947.25	989.45	3.69	
AS	240	64400.25	268.33		
Total	299	200063.06			

The alpha count mean scores and their associated standard deviations for the six treatments are shown in Table XI below.

TABLE XI

ALPHA COUNT MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cum-num Prob	Color Stress	Syringe Stress	Total
High	Mean	120.08	300.60	305.88	255.76	305.40	281.64	261.56
	S.D.	54.7	28.7	22.3	59.7	30.3	33.0	77.4
Low	Mean	176.92	303.28	307.12	263.00	304.44	289.56	274.05
	S.D.	96.4	30.1	28.4	78.8	42.9	41.4	74.9
Total	Mean	148.50	301.94	306.50	259.38	304.92	285.60	
	S.D.	84.2	29.7	25.8	70.7	37.4	38.1	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table XII below. Included in this table is a graphic representation of the mean score values.

TABLE XII

ALPHA COUNT SCHEFFÉ ANALYSIS

S indicates $p<.05$

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

					6
				5	
			4	S	
		3	S		
	2		S		
1	S	S	S	S	S

Treatment

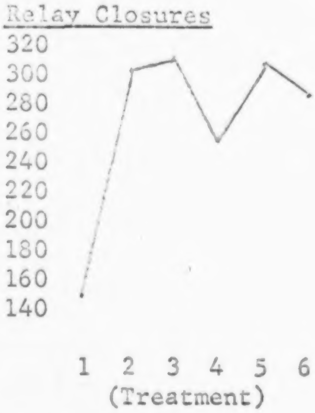
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the alpha counter can be found in Table XIII on page 39. The Within Subjects F statistic of 84.70 indicates significance at the .05 level with respect to variability among the means of the six treatments. This further supports the hypothesis, with relation to alpha count, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

A simple ANOVA comparing high and low groups for each treatment condition resulted in a significant F statistic for the resting treatment of 6.3 which is significant at the .025 level, and is shown in Appendix C. A simple ANOVA comparing high and low groups for each of the other five treatment conditions resulted in no significant differences.

TABLE XIII

ALPHA COUNT REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	11706.25	11706.25	2.37	
Subjects(s)	48	237217.75	4942.04		
Within Subjects					
A	5	933067.25	186613.45	84.70	$p < .05$
AB	5	30238.25	6047.65	2.74	
AS	240	528787.50	2203.28		
Total	299	1741017.00			

DATA RELATED TO BETA BRAIN WAVE MEASUREMENTS

The beta time mean scores and their associated standard deviations for the six treatments can be found in Table XIV below.

TABLE XIV

BETA TIME MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cumnum Prob	Color Stress	Syringe Stress	Total
High	Mean	58.57	117.32	119.26	89.50	115.56	93.87	99.01
	S.D.	21.5	27.9	25.4	34.6	32.7	35.7	37.1
Low	Mean	47.54	119.04	120.01	91.09	132.45	105.28	102.57
	S.D.	17.6	30.1	31.6	34.1	27.6	30.9	40.4
Total	Mean	53.05	118.18	119.64	90.30	124.00	99.57	
	S.D.	20.6	29.4	29.0	34.7	31.8	34.3	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table XV below. Included in this table is a graphic representation of the mean score values.

TABLE XV

BETA TIME SCHEFFÉ ANALYSIS

S indicates p<.05

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

	1	2	3	4	5	6
1		S	S	S	S	S
2				S		S
3				S		S
4					S	
5						S

Treatment

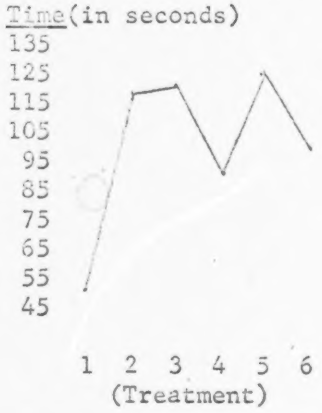
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the beta clock is presented in Table XVI on page 41. The Within Subjects F statistic of 70.47 indicates significance at the .05 level with respect to variability among the means of the six treatments. This further supports the hypothesis, with relation to beta time, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress." A simple ANOVA comparing high and low groups for each treatment condition resulted in no significant differences.

TABLE XVI

BETA TIME REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	952.22	952.22	.32	
Subjects(s)	48	141539.81	2948.75		
Within Subjects					
A	5	179344.50	35868.90	70.47	$p < .05$
AB	5	5837.09	1167.42	2.29	
AS	240	122158.56	508.99		
Total	299	449832.19			

The beta count mean scores and their associated standard deviations for the six treatments appear in Table XVII below.

TABLE XVII

BETA COUNT MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cum num Prob	Color Stress	Syringe Stress	Total
High	Mean	365.20	430.04	449.56	427.40	418.20	398.16	414.75
	S.D.	84.4	66.5	61.8	93.4	98.1	99.9	89.8
Low	Mean	325.60	420.16	412.52	427.28	360.72	427.08	395.56
	S.D.	87.4	82.5	79.3	78.7	94.2	80.4	92.7
Total	Mean	345.40	425.10	431.04	427.34	389.44	412.62	
	S.D.	89.1	75.9	74.2	87.3	101.4	92.8	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table XVIII on page 42. Included in this table is a graphic representation of the mean score values.

TABLE XVIII

BETA COUNT SCHEFFÉ ANALYSIS

S indicates p<.05

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

	2	3	4	5	6
1	S	S	S		S

Treatment

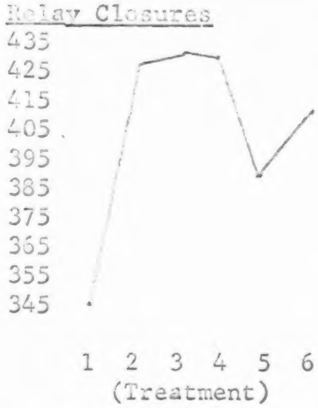
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the beta counter is shown in Table XIX on page 43. The Within Subjects F statistic of 8.08 indicates significance at the .05 level with respect to variability among the means of the six treatments. This further supports the hypothesis, with relation to beta count, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

A simple ANOVA comparing high and low groups for each treatment condition resulted in a significant F statistic for the color stress treatment of 4.3 which is significant at the .05 level, and is shown in Appendix C. A simple ANOVA comparing high and low groups for each of the other five treatment conditions resulted in no significant differences.

TABLE XIX

BETA COUNT REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	27629.00	27629.00	2.48	
Subjects(s)	48	534819.50	11142.07		
Within Subjects					
A	5	271668.00	54333.60	8.08	$p < .05$
AB	5	62038.50	12407.70	1.84	
AS	240	1614501.50	6727.09		
Total	299	2510656.50			

DATA RELATED TO SUB-LEVEL BRAIN WAVE MEASUREMENTS

The equipment was wired in such a way that, when none of the three brain waves produced by the subject were at or above the 10uv level, a fourth clock and separate counter tabulated the duration and extent of this state. The statistical analysis of this data is presented for completeness in reporting; however, conclusions from the analyses of these findings should be cautiously considered until such time as further research fully indicates their significance.

The sub-level time mean scores and their associated standard deviations for the six treatments are presented in Table XX on page 44.

TABLE XX

SUB-LEVEL TIME MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cum-num Prob	Color Stress	Syringe Stress	Total
High	Mean	12.21	22.48	17.13	29.81	24.42	34.12	23.36
	S.D.	12.1	14.7	9.4	20.6	19.2	23.4	18.8
Low	Mean	26.45	22.35	18.83	34.24	16.64	30.03	24.75
	S.D.	30.5	17.1	15.9	27.3	17.1	24.6	23.7
Total	Mean	19.33	22.42	17.98	32.03	20.53	32.07	
	S.D.	24.5	16.1	13.2	24.5	18.7	24.4	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table XXI below. Included in this table is a graphic representation of the mean score values.

TABLE XXI

SUB-LEVEL TIME SCHEFFÉ ANALYSIS

S indicates $p < .05$

1 vs 2,3,4 -
1 vs 5,6 -
2,3,4 vs 5,6 -

					6
				5	S
			4	S	
		3	S		S
	2				
1			S		S

Treatment

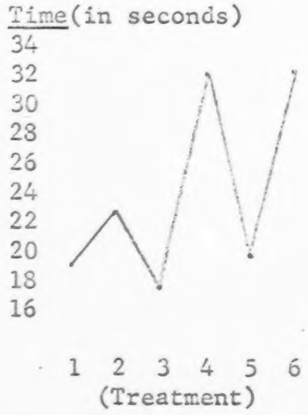
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the sub-level clock is presented in Table XXII below. The Within Subjects F statistic of 8.03 indicates significance at the .05 level with respect to variability among the means of the six treatments. This may further support the hypothesis, with relation to sub-level time, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

A simple ANOVA comparing high and low groups for each treatment condition resulted in a significant F statistic for the resting treatment of 4.5 which is significant at the .05 level, and is shown in Appendix C. A simple ANOVA comparing high and low groups for each of the other five treatment conditions resulted in no significant differences.

TABLE XXII

SUB-LEVEL TIME REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	145.40	145.40	.11	
Subjects(s)	48	62060.00	1292.92		
Within Subjects					
A	5	10110.87	2022,17	8.03	$p<.05$
AB	5	3637.75	727.55	2.89	
AS	240	60437.11	251.82		
Total	299	136391.14			

The sub-level count mean scores and their associated standard deviations for the six treatments are in Table XXIII on page 46.

TABLE XXIII

SUB-LEVEL COUNT MEAN SCORES

		Resting	Math Prob	Conceptual Prob	Cum-num Prob	Color Stress	Syringe Stress	Total
High	Mean	83.48	210.44	183.40	207.60	214.08	246.96	190.99
	S.D.	51.8	89.0	62.2	75.2	97.2	129.3	102.2
Low	Mean	132.32	206.48	174.56	220.00	165.48	219.60	186.41
	S.D.	91.3	93.7	82.3	106.1	96.6	117.3	98.9
Total	Mean	107.90	208.46	178.98	213.80	189.78	233.28	
	S.D.	79.0	92.3	73.8	93.1	101.0	112.3	

A Scheffé analysis indicating significance of difference between total treatment mean scores appears in Table XXIV below. Included in this table is a graphic representation of the mean score values.

TABLE XXIV

SUB-LEVEL COUNT SCHEFFÉ ANALYSIS

S indicates p<.05

1 vs 2,3,4 - S
1 vs 5,6 - S
2,3,4 vs 5,6 -

					6
				5	
			4		
		3			S
	2				
1	S	S	S	S	S

Treatment

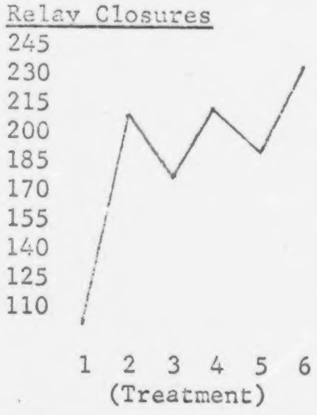
1. Rest

Problem Solving

2. Mathematical
3. Conceptualization
4. Cumulative Number Adding

Stress

5. Color
6. Syringe



The two dimensional repeated measures analysis for data recorded on the sub-level counter is shown in Table XXV below. The Within Subjects F statistic of 19.16 indicates significance at the .05 level with respect to variability among the means of the six treatments. This may further support the hypothesis, with relation to sub-level count, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

A simple ANOVA comparing high and low groups for each treatment condition resulted in a significant F statistic for the resting treatment of 5.2 which is significant at the .05 level, and is shown in Appendix C. A simple ANOVA comparing high and low groups for each of the other five treatment conditions resulted in no significant differences.

TABLE XXV

SUB-LEVEL COUNT REPEATED MEASURES ANALYSIS

Source	DF	SS	MS	F	
Among Subjects					
B	1	1577.87	1577.87	.06	
Subjects(s)	48	1254193.87	26129.04		
Within Subjects					
A	5	481606.37	96321.27	19.16	$p < .05$
AB	5	70215.37	14043.07	2.79	
AS	240	1206779.62	5028.25		
Total	299	3014373.12			

SUMMARY OF FINDINGS

The two dimensional repeated measures analysis of data recorded for all treatment conditions indicated significance at the .05 level with respect to variability among the means of the six treatments. This supports the hypothesis, with relation to theta-alpha-beta time and count, that: "Brain wave patterns would be different, depending whether the subjects were resting, solving problems, or under stress."

The simple ANOVA analyses comparing high and low groups for each treatment condition involved forty-eight calculations. Four of the eight calculations involved in the resting treatment indicated significance at the .05 level. These four were the time and count analyses for alpha and sub-level readings. Of the remaining forty ANOVA calculations only the one dealing with beta count during the color stress treatment was significant (p .05). Thus, of forty-eight simple ANOVA analyses only five were significant at the .05 level. Since only 10.4% of the calculations are significant, a figure closely approaching chance, it is not possible to conclude that: "High and low grade point average students would have differing brain wave patterns."

CHAPTER V

SUMMARY AND SUGGESTIONS FOR FUTURE RESEARCH

SUMMARY OF STUDY

Hypotheses and Subjects. This study investigated the hypotheses that (1) brain wave patterns would significantly differ depending on whether the subjects were resting, solving problems, or under stress and that (2) high and low grade point average students would have differing brain wave patterns. The subjects were senior midshipmen at the United States Naval Academy. The high group was comprised of those whose cumulative grade point average was between 3.50 and 4.00; the low group was comprised of those whose cumulative grade point average was between 2.00 and 2.25.

Experimental Treatment and Instrumentation. The study involved the application of six different treatments over a seventeen minute total testing time. Brain wave measurements were recorded as the subjects were: (1) resting, (2) working a mathematics problem, (3) working a conceptualization problem, (4) doing cumulative number adding, (5) reacting to stress introduced into a reading exercise, and (6) reacting to stress induced by preparing to have blood drawn from their arm. An EEG was used to detect brain waves in the dependent variable. The amplified brain wave signal was then simultaneously separated into its theta-alpha-beta brain wave components. The amount of time spent in each brain wave state above a predetermined level during each treatment was recorded, as well as the number of times the brain wave signal went above and below the prescribed threshold.

Statistical Analysis. Since six different treatments were applied, a two dimensional repeated measures design was employed in recognition of the effect each treatment might have on those that followed. This approach allowed for the analysis of the significance of the difference between treatment means in light of the interrelationship between treatment applications.

Because the assumption of homogeneity of equicovariance was not supported, a simple analysis of variance was calculated comparing means among subjects for each treatment.

FINDINGS

With respect to the fifty students tested, this study has found that there are significant differences in brain wave patterns depending whether subjects are resting, solving problems, or under stress. This result confirms findings by others that techniques exist for measuring brain wave activity which are capable of differentiating between some behaviors (treatments).

This project also attempted to determine whether significant differences exist between high and low grade point average students with respect to the production of brain waves during resting, problem solving, and stress treatments. Only five (10.4%) of the forty-eight ANOVA comparisons made to determine whether differences existed were significant at the .05 level; this result could be explained to occur by chance. The use of a stratified random sample as well as the possible uniqueness of the subjects mitigates against applying a liberal interpretation to the significance of the data analyzed in this research.

CONCLUSIONS AND IMPLICATIONS

The first hypothesis of this study was that differing treatments (resting, solving problems, or under stress) would produce significantly different brain waves for all subjects. Within the assumptions and limitations listed in Chapter I, this hypothesis was supported with all statistical evaluations being significant at the .05 level.

The utility of establishing that differing treatments produce significantly different brain waves may well be that a method of automatically detecting some behavior (i.e., treatment) changes can be developed. An extension of this concept is the possibility that student shifts from problem solving to resting may be detected in such a way as to alert the student that, in fact, he is no longer paying attention to his studies.

Another implication of this detection capability is that future researchers may be able to more accurately determine the attention given by subjects to various tasks they are performing as part of a study.

The second hypothesis was that identical treatments applied to students who had high and low grade point averages would result in the production of statistically significant differences in their brain wave patterns. This hypothesis is not supported by the statistical findings because only 10.4% of the evaluations were found to be significant and this could have occurred by chance. However, it can not be concluded from the results of this study that there are not differences between high and low. This aspect of the study may have been influenced by the fact that the subjects generally fell within the top 30% of their high school graduating class. Thus, although high and low groups were used, even the bottom group could be much higher in its academic potential than the rest of the population.

The study has provided further evidence of the capability that exists to measure brain waves in a way which will permit comparisons between groups. Before results can be operationally relied upon it will be necessary to conduct further research with more heterogeneous groups. In addition, it will be necessary to increase sample size so that results can be related to groups other than the one studied.

SUGGESTIONS FOR FUTURE RESEARCH

The following questions generated by the findings of this study deserve further research effort:

(1) Do the results of this study hold up for other groups?

(2) Does a significant difference in brain wave patterns exist between high and low academic achievers with relation to the general population?

(3) Does the cost of measuring brain wave differences justify the expense and provide more useful information than is already available with paper and pencil tests?

(4) Is there a relationship between theta-alpha-beta brain waves and scores on psychological tests?

(5) Is there a difference in brain wave patterns between creative and non-creative persons?

(6) Do parents and their children show similar brain wave patterns within the same type of treatment situations?

(7) Does the very act of brain wave measurement have more or less effect on the results than the act of a person taking a paper and pencil test?

APPENDIX A

DATA COLLECTION SHEET

APPENDIX A

DATA COLLECTION SHEET

Name Date Student Identification #

Test #

1 - Cumulative grade point average after six full semesters(QPR)

2 - Verbal aptitude CEEB score

3 - Mathematics aptitude CEEB score

4 - English composition achievement CEEB score

5 - Mathematics achievement CEEB score

6 - Rank in high school class (converted to a 200-800 score)

7 - High school recommendation score (converted to a 200-800 score)

8 - High school extra-curricular activities score (converted to a 200-800 score)

9 - USNA whole man multiple score

10 - Plebe score on the Cornell Word From Test CWF 2

11 - The number 5 indicates that the person does suffer from hay fever, the number 15 indicates the person does not suffer from hay fever

12 - The number 5 indicates that the person is left handed, the number 15 indicates that the person is right handed

Brain Wave Analysis

3 minutes resting			3 minutes mathematics problem		
	Time	Count		Time	Count
theta	Test 13	Test 14	theta	Test 21	Test 22
alpha	Test 15	Test 16	alpha	Test 23	Test 24
beta	Test 17	Test 18	beta	Test 25	Test 26
sub-level	Test 19	Test 20	sub-level	Test 27	Test 28
(Treatment #1)			(Treatment #2)		

3 minutes conceptual problem

	Time	Count
theta	Test 29	Test 30
alpha	Test 31	Test 32
beta	Test 33	Test 34
sub-level	Test 35	Test 36

(Treatment #3)

3 minute cumulative number adding

	Time	Count
theta	Test 37	Test 38
alpha	Test 39	Test 40
beta	Test 41	Test 42
sub-level	Test 43	Test 44

(Treatment #4)

1 minute color stress test(*)

	Time	Count
theta	Test 45	Test 46
alpha	Test 47	Test 48
beta	Test 49	Test 50
sub-level	Test 51	Test 52

(Treatment #5)

1 minute syringe stress test(*)

	Time	Count
theta	Test 53	Test 54
alpha	Test 55	Test 56
beta	Test 57	Test 58
sub-level	Test 59	Test 60

(Treatment #6)

Total time under stress(5&6)

	Time	Count
theta	Test 61	Test 62
alpha	Test 63	Test 64
beta	Test 65	Test 66
sub-level	Test 67	Test 68

Total problem solving time(2&3&4)

	Time	Count
theta	Test 69	Test 70
alpha	Test 71	Test 72
beta	Test 73	Test 74
sub-level	Test 75	Test 76

An * indicates that these figures were multiplied by a factor of three when the analysis for repeated measures design was done so that all data would be in 3 minute increments.

All measurements in theta-alpha-beta were at the 10 microvolt level with sub-level times and counts indicating the amounts of these factors when none of the three states were above the 10 microvolt level.

All measurements were taken between O1 and T3 with a ground wire at the middle of the forehead. (G1 placed at O1, and G2 at T3). These locations are in accordance with the International Electrode placement system.

APPENDIX B

RAW SCORES FOR TEST NOS. 1 THROUGH 76

APPENDIX B

RAW SCORES FOR TEST NOS. 1 THROUGH 76

Table Page

B1 Test Nos. 1 - 6 59

B2 Test Nos. 7 - 12 60

B3 Test Nos. 13 - 18 61

B4 Test Nos. 19 - 24 62

B5 Test Nos. 25 - 30 63

B6 Test Nos. 31 - 36 64

B7 Test Nos. 37 - 42 65

B8 Test Nos. 43 - 48 66

B9 Test Nos. 49 - 54 67

B10 Test Nos. 55 - 60 68

B11 Test Nos. 61 - 66 69

B12 Test Nos. 67 - 72 70

B13 Test Nos. 73 - 76 71

The sequence of subject data presentation is determined by the individual's cumulative grade point average. The first score is that of the man with the highest cumulative grade point average (QPR) and the next twenty-four scores are in descending order of QPR for the rest of the high group. The twenty-sixth score is that individual with the highest QPR in the low group and the fiftieth score belongs to the man with the lowest QPR in the low group.

T#1	T#2	T#3	T#4	T#5	T#6
3.93	[illegible]	732	[illegible]	[illegible]	775
3.92	[illegible]	675	553		
3.92	576	723	677	[illegible]	575
3.90	747	500	709	[illegible]	725
3.88	817	640	724	677	[illegible]
3.86	774	675	776	[illegible]	[illegible]
3.84	830	771	616	735	750
3.83	790	640	[illegible]	702	[illegible]
3.82	762	659	[illegible]	720	720
3.81	757	712	[illegible]	775	775
3.75	582	595	[illegible]	[illegible]	525
3.74	712	704	569	[illegible]	725
3.68	599	732	629	[illegible]	625
3.68	[illegible]	585	633	[illegible]	575
3.63	555	684	475	[illegible]	475
3.60	564	723	548	701	500
3.60	523	654	547	[illegible]	525
3.59	605	741	533	[illegible]	725
3.58	609	654	657	[illegible]	520
3.58	665	694	627	[illegible]	550
3.57	575	751	659	[illegible]	[illegible]
3.56	567	541	[illegible]	753	525
3.55	541	623	521	[illegible]	625
3.55	534	742	526	790	550
3.50	531	712	497	731	525
2.24	504	650	605	645	[illegible]
2.24	582	559	574	545	525
2.23	503	538	610	529	575
2.22	524	659	533	654	401
2.22	562	636	515	587	475
2.21	541	540	431	596	450
2.21	665	550	608	576	401
2.20	586	665	597	576	500
2.20	537	655	580	540	350
2.19	544	741	698	595	550
2.18	537	705	562	665	670
2.17	522	641	491	665	500
2.16	541	646	532	598	500
2.16	562	694	497	669	400
2.16	522	732	530	740	475
2.16	546	569	565	560	475
2.14	514	768	544	650	575
2.14	538	578	550	576	525
2.13	557	571	574	661	525
2.12	599	576	508	521	575
2.11	562	627	610	596	575
2.10	610	521	574	598	550
2.07	506	569	538	553	425
2.06	473	713	521	676	500
2.05	514	576	491	620	625

T#7	T#8	T#9	T#10	T#11	T#12
800	455	[illegible]	4	15	15
775	525	[illegible]	2	15	15
775	535	57131	1	15	15
775	500	[illegible]	3	15	15
767	435	61457	1	15	15
738	365	[illegible]	4	15	5
775	675	77233	4	15	15
800	480	57172	3	15	15
800	525	52980	1	15	5
750	370	70641	[illegible]	15	15
750	415	55636	[illegible]	5	15
750	365	56630	3	15	15
700	415	61365	3	15	15
738	545	54174	5	5	5
713	550	50273	1	15	15
558	340	56574	1	15	15
775	590	62279	0	5	15
800	505	67360	0	15	15
725	310	55945	3	15	15
775	490	62582	9	5	15
800	360	61296	10	15	15
750	455	60772	1	15	15
775	650	63159	0	15	15
738	350	59692	9	15	15
750	550	63575	9	15	5
425	355	49329	5	15	15
800	675	62044	1	15	15
775	400	55193	4	15	15
750	515	56150	1	15	15
750	420	54195	2	15	5
600	400	49510	6	15	15
556	335	49352	2	15	15
650	405	55693	2	15	5
550	300	53926	4	15	15
525	620	64454	1	15	15
725	750	65382	2	15	15
775	380	54420	2	15	15
700	460	57164	10	15	15
675	400	53236	2	15	15
550	650	61263	6	15	15
775	650	58673	9	15	15
750	710	67927	10	15	15
767	560	57661	0	5	5
425	550	55493	7	5	15
750	545	57928	3	15	15
750	570	55427	1	5	15
750	555	58005	0	5	15
700	275	47788	2	15	15
619	235	50389	3	15	15
733	650	63023	4	15	15

T#13	T#14	T#15	T#16	T#17	T#18
103.22	231	[illegible]	[illegible]	[illegible]	[illegible]
76.76	194	[illegible]	[illegible]	55.01	[illegible]
132.91	[illegible]	171.97	75	[illegible]	[illegible]
108.28	241	155.70	152	[illegible]	[illegible]
91.03	222	160.45	74	[illegible]	[illegible]
149.38	213	174.17	[illegible]	[illegible]	[illegible]
145.01	215	173.24	67	37.22	[illegible]
104.54	247	157.03	93	104.20	[illegible]
82.29	159	150.19	213	43.58	[illegible]
61.25	173	158.52	178	37.37	[illegible]
120.76	231	169.54	103	[illegible]	[illegible]
92.02	215	170.12	91	[illegible]	[illegible]
90.41	146	151.05	203	[illegible]	[illegible]
147.37	150	169.28	107	70.15	421
110.63	257	172.24	71	43.70	337
61.04	210	162.53	113	75.94	432
67.53	214	158.73	153	52.15	371
64.60	157	143.64	139	57.14	250
135.21	236	173.17	37	52.94	357
120.49	274	174.01	56	64.16	354
65.96	136	158.53	158	55.96	[illegible]
150.85	140	147.98	231	64.98	332
114.95	241	165.35	135	73.64	520
97.75	240	165.53	105	40.65	547
111.68	236	162.35	158	93.10	513
109.78	232	165.02	49	44.32	[illegible]
117.42	244	175.73	38	45.53	299
55.30	160	146.29	179	77.73	393
95.31	231	175.78	30	50.68	301
116.68	253	169.82	80	41.49	257
133.28	192	160.80	139	44.[illegible]	341
61.65	207	124.03	285	51.18	393
91.39	215	113.22	370	29.79	282
51.06	150	145.54	226	69.15	430
100.90	241	171.76	83	58.08	413
73.21	177	115.67	220	25.56	229
3.28	13	53.56	166	12.10	51
23.28	76	94.21	266	38.40	252
142.81	171	155.73	187	24.10	232
118.07	238	171.21	76	71.38	[illegible]
145.67	215	171.65	75	44.04	322
68.34	151	130.58	261	38.78	320
95.18	213	167.84	112	76.22	[illegible]
10.81	37	82.74	269	29.87	246
45.10	223	148.75	226	47.33	343
97.02	225	130.47	291	34.47	275
105.57	221	153.33	168	50.46	[illegible]
114.71	219	136.62	258	56.03	405
133.64	245	173.60	49	61.41	419
13.07	48	86.32	282	35.14	275

T#19	T#20	T#21	T#22	T#23	T#24
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	161	[illegible]	115	[illegible]	[illegible]
9.91	36	[illegible]	242	[illegible]	[illegible]
15.45	11	[illegible]	91	[illegible]	[illegible]
9.30	59	77.15	121	113.[illegible]	317
.95	16	[illegible]	113	[illegible]	[illegible]
1.59	[illegible]	[illegible]	152	152.[illegible]	[illegible]
2.55	41	97.01	233	153.[illegible]	[illegible]
39.12	19[illegible]	[illegible]	107	41.2[illegible]	327
31.9[illegible]	139	91.57	105	9[illegible].77	[illegible]
3.17	51	31.79	[illegible]	152.63	[illegible]
3.92	71	57.23	153	127.[illegible]	[illegible]
41.44	10[illegible]	[illegible]	177	113.07	321
1.51	22	12.[illegible]	217	150.15	[illegible]
3.72	52	57.[illegible]	142	12[illegible].51	325
11.69	102	71.73	212	[illegible]	[illegible]
16.75	105	51.52	175	150.67	[illegible]
31.25	135	40.[illegible]	[illegible]	[illegible].71	[illegible]
3.31	24	73.[illegible]	203	157.36	[illegible]
2.94	30	53.55	212	130.54	[illegible]
19.23	147	34.[illegible]	120	152.29	342
10.67	76	37.77	132	137.24	335
3.65	57	51.90	219	147.31	274
7.56	72	33.10	113	119.61	291
6.61	34	52.67	165	129.62	302
7.22	33	44.53	137	105.20	329
1.27	16	71.91	194	135.93	267
20.22	140	75.9[illegible]	199	119.33	325
1.67	16	74.02	205	130.25	27[illegible]
5.60	53	106.0[illegible]	227	155.02	219
9.69	53	66.45	169	139.25	302
24.52	200	55.74	171	111.11	317
33.40	236	40.66	146	109.47	332
32.81	190	40.12	134	98.47	337
4.20	54	53.11	163	132.17	[illegible]
45.42	197	24.12	92	73.75	29[illegible]
119.1	203	31.35	113	104.94	320
71.21	274	29.31	109	96.27	325
8.67	74	34.26	125	102.58	312
9.56	41	87.07	213	129.13	326
2.03	20	56.66	167	124.31	311
36.30	212	37.00	127	83.62	314
5.69	74	43.43	220	152.62	227
43.56	292	49.72	155	120.47	317
20.91	164	67.78	198	137.57	291
27.63	178	51.95	167	116.91	34[illegible]
11.10	104	32.23	196	142.77	280
17.58	140	69.97	203	139.02	[illegible]
1.04	20	49.69	170	104.32	317
60.51	304	60.21	167	136.00	296

T#25	T#26	T#27	T#28	T#29	T#30
110.20	475	[illegible]	[illegible]	[illegible]	[illegible]
82.71	451	45.30	251	55.50	157
151.10	359	5.12	5	61.91	[illegible]
95.40	491	45.62	354	47.52	[illegible]
137.93	353	13.10	15	52.30	[illegible]
62.43	439	47.99	317	59.13	197
58.94	461	29.66	249	57.09	[illegible]
159.94	261	2.2	57	113.90	232
94.27	499	44.66	336	52.49	151
92.17	525	36.37	306	61.32	172
117.02	499	16.63	19	79.94	[illegible]
133.80	416	14.62	179	57.91	[illegible]
99.17	510	26.36	244	75.72	215
145.16	356	4.70	70	75.15	195
126.74	451	17.02	229	52.73	152
141.73	362	9.96	137	72.96	204
134.41	435	11.90	134	53.26	190
91.35	469	40.01	204	60.80	173
137.63	419	10.23	150	73.82	199
145.54	355	4.09	110	105.58	234
94.57	495	35.62	320	45.41	151
126.94	464	23.02	274	46.11	142
144.91	359	5.05	39	106.21	221
110.84	509	25.20	270	65.26	195
144.67	363	10.32	135	54.51	173
66.38	410	44.25	290	36.82	215
155.62	273	5.32	94	79.05	207
122.07	475	16.39	205	95.27	[illegible]
135.01	459	9.24	137	95.00	230
165.62	176	1.00	27	103.90	229
145.31	378	6.58	126	56.06	223
106.93	516	26.77	256	76.33	212
115.66	462	27.83	261	54.43	171
54.46	398	49.48	322	62.40	179
126.33	449	16.16	153	58.64	177
73.53	418	64.46	321	51.19	164
131.31	456	21.17	279	63.33	190
106.17	502	36.62	336	62.08	[illegible]
111.68	496	32.96	300	48.00	157
125.64	482	10.65	155	110.69	207
63.48	464	23.95	237	49.83	216
68.98	461	54.91	367	52.97	160
156.53	274	3.12	57	102.74	225
117.75	495	20.72	233	60.75	170
145.46	355	8.22	117	74.64	217
140.23	379	13.27	133	49.20	154
144.70	408	6.01	102	59.42	173
146.39	344	6.43	110	30.54	206
92.48	514	35.22	301	91.07	223
133.54	453	10.95	158	49.56	163

T#31	T#32	T#33	T#34	T#35	T#36
131.79	311	140.44	373	[illegible]	137
117.65	309	99.12	345	37.06	261
132.94	295	131.19	445	10.20	15
124.74	307	123.13	457	19.57	217
124.19	308	124.75	350	17.13	159
123.23	314	85.50	320	24.21	222
127.15	299	59.04	315	31.62	247
145.50	286	146.45	304	3.75	75
118.11	327	110.63	511	22.53	227
101.52	336	85.83	471	35.92	265
140.93	283	129.12	502	9.31	131
110.63	339	127.96	446	13.37	272
125.06	307	123.04	490	14.64	135
141.55	273	115.95	507	12.41	135
119.61	325	120.43	455	22.15	220
129.60	306	143.09	376	3.32	124
125.91	322	123.63	491	15.16	201
114.65	296	96.93	550	20.62	245
130.25	316	137.74	426	10.68	135
150.60	249	151.11	675	2.70	56
105.33	337	100.13	502	33.65	294
124.92	324	135.60	445	14.50	203
150.64	279	151.97	354	2.21	57
132.52	301	121.21	499	14.16	171
119.60	313	123.52	465	17.44	232
123.14	312	67.07	503	21.54	203
145.11	284	150.66	336	3.92	75
130.97	296	151.71	317	5.86	17
147.33	256	129.99	501	8.10	73
141.65	310	153.14	503	4.42	35
144.31	257	157.43	290	3.22	55
142.42	276	128.97	404	3.92	135
119.13	322	134.42	411	16.01	192
106.10	337	52.95	379	41.67	267
127.63	335	101.73	514	21.31	245
102.40	342	116.00	470	27.25	259
131.05	310	141.65	378	11.55	154
97.69	323	126:23	459	22.93	256
106.65	317	123.29	462	23.17	255
131.24	317	160.52	257	2.73	51
131.84	315	91.01	515	16.52	159
93.57	330	79.85	465	42.94	305
156.39	230	152.57	360	1.95	47
122.14	318	115.07	434	23.21	210
133.00	305	146.67	360	7.87	127
76.65	282	57.86	357	58.07	255
109.71	344	76.82	422	36.42	264
143.11	282	152.91	309	5.26	92
125.31	335	123.63	507	12.29	157
107.37	332	88.17	510	35.17	269

T#37	T#38	T#39	T#40	T#41	T#42
[illegible]	[illegible]	141.74	[illegible]	[illegible]	[illegible]
37.32	119	117.15	274	[illegible]	[illegible]
[illegible]	204	140.58	241	137.51	[illegible]
[illegible]	203	145.25	323	120.58	[illegible]
52.49	157	114.42	337	[illegible]	[illegible]
[illegible]	97	104.15	292	[illegible]	[illegible]
34.60	123	114.53	273	[illegible]	[illegible]
53.71	159	132.99	299	179.53	[illegible]
30.03	106	75.79	[illegible]	69.20	[illegible]
26.07	72	79.61	279	74.38	[illegible]
55.02	174	139.37	291	77.38	[illegible]
40.30	144	111.51	[illegible]	115.84	[illegible]
90.59	221	159.49	177	124.58	[illegible]
92.47	226	151.35	309	101.27	[illegible]
22.16	90	105.46	337	[illegible]	[illegible]
57.97	105	121.04	157	37.30	[illegible]
[illegible]	152	131.57	222	79.85	[illegible]
94.73	159	147.94	219	111.94	[illegible]
112.11	232	168.97	169	126.11	[illegible]
69.16	207	140.47	267	159.34	[illegible]
21.46	69	94.51	253	46.62	221
30.02	111	105.47	355	139.65	415
59.91	206	129.39	310	117.52	499
54.66	171	152.05	149	30.51	259
34.53	124	110.35	308	109.22	505
119.46	266	173.99	52	50.79	375
65.13	195	137.87	305	130.01	[illegible]
49.34	156	115.47	300	99.73	529
74.60	198	134.40	219	51.78	453
127.58	242	167.49	105	134.93	400
82.58	214	149.25	279	150.35	257
72.90	203	126.50	316	94.59	325
51.12	160	104.70	351	90.38	[illegible]
51.01	157	119.95	[illegible]	111.62	470
41.08	136	125.23	271	85.21	534
23.53	75	53.61	255	31.22	269
15.15	62	82.76	310	72.24	471
33.26	114	105.60	267	49.21	370
57.23	181	116.22	369	126.64	[illegible]
37.59	224	158.20	179	153.31	314
51.16	163	112.11	255	63.11	434
34.92	79	78.42	307	48.42	300
62.28	186	141.17	278	135.34	425
37.65	124	107.71	317	108.45	304
45.77	151	120.57	319	104.66	462
15.14	57	52.92	230	53.61	[illegible]
35.58	109	105.43	284	53.30	290
44.64	142	97.79	315	71.93	471
[illegible]	270	171.84	69	109.72	473
11.77	45	79.44	307	63.82	435

T#43	T#44	T#45	T#46	T#47	T#48
14.25	150	14.07	51	37.15	115
47.65	235	22.51	60	43.72	107
14.54	157	[illegible]	57	49.45	121
15.04	150	20.65	65	34.42	[illegible]
34.60	282	13.56	47	27.14	115
55.10	322	13.92	60	37.10	93
50.72	204	13.56	69	33.50	105
13.68	177	33.32	73	50.91	[illegible]
74.61	282	11.04	53	30.55	[illegible]
64.06	341	19.41	55	27.75	[illegible]
21.04	262	21.24	64	43.97	95
27.69	263	23.54	70	40.31	2
5.35	3	15.40	47	37.77	112
10.26	115	23.33	69	45.94	101
40.66	335	15.17	52	43.67	115
49.01	204	9.55	35	30.62	102
32.63	210	23.54	30	35.28	[illegible]
13.32	190	13.26	41	34.04	[illegible]
3.01	40	29.50	71	44.77	[illegible]
5.13	120	10.80	52	37.50	111
69.65	239	9.30	37	30.98	[illegible]
16.25	245	10.72	54	41.38	94
13.66	174	31.52	79	49.38	90
29.43	142	5.07	30	26.56	107
31.16	257	26.51	59	43.40	96
1.57	23	24.11	65	44.42	107
12.01	164	20.51	57	44.12	97
29.15	269	24.21	64	42.20	103
19.52	184	30.58	77	47.33	[illegible]
2.29	35	42.66	73	52.47	94
3.17	51	23.44	76	47.77	85
19.51	190	22.50	64	40.65	112
34.36	292	16.36	52	33.34	109
24.65	239	9.64	34	23.00	102
25.22	244	27.45	77	49.32	[illegible]
95.33	290	9.46	35	29.83	121
63.07	370	[illegible]	64	45.67	95
54.84	279	10.50	39	32.16	104
17.35	230	13.92	40	39.44	110
1.93	52	26.13	70	41.55	[illegible]
45.32	263	22.00	65	41.04	105
66.86	328	5.23	32	26.06	95
9.93	137	33.62	70	51.14	93
32.59	278	19.43	57	41.83	112
27.37	247	37.05	67	50.01	85
90.50	346	29.56	64	40.56	109
54.92	253	24.07	60	42.65	93
40.46	310	17.50	57	42.30	119
1.74	31	20.16	59	37.65	115
63.59	377	13.75	51	35.93	127

T#49	T#50	T#51	T#52	T#53	T#54
[illegible]	157	7.53	[illegible]	8.01	51
45.99	157	[illegible]	33	32.85	74
48.59	153	5.53	7	22.59	75
47.83	125	[illegible]	43	10.83	71
23.70	144	10.75	120	20.74	[illegible]
27.40	170	12.35	25	14.52	49
24.00	165	13.50	104	20.71	57
34.37	53	.51	11	24.00	[illegible]
36.17	165	12.38	110	7.62	76
24.37	163	17.32	103	15.77	[illegible]
40.10	175	4.16	33	16.26	73
33.42	73	.60	21	16.00	57
33.16	179	9.72	54	14.28	63
40.73	160	4.58	54	23.04	70
49.48	111	3.35	45	13.04	47
26.83	149	17.44	105	4.73	21
45.61	129	4.09	59	12.12	53
32.27	161	10.67	92	9.79	51
47.54	132	1.95	37	17.51	35
35.71	176	7.99	43	21.39	39
20.73	142	13.53	120	6.65	23
46.57	113	4.00	56	5.34	10
50.46	97	1.27	28	29.23	32
22.19	128	19.15	115	7.03	23
51.14	94	1.51	30	14.13	52
43.14	160	3.31	50	19.69	54
46.27	131	2.41	40	15.21	51
52.31	94	1.39	37	15.16	50
50.38	113	1.25	26	17.38	47
55.47	57	.21	3	21.92	55
54.44	73	.60	16	25.32	55
45.18	134	3.94	57	16.69	50
43.60	113	5.10	62	11.61	43
16.51	125	21.42	112	14.52	44
47.73	123	1.64	26	12.42	45
27.41	150	15.93	115	3.03	10
45.50	117	2.38	40	10.56	41
36.73	146	11.58	99	13.42	44
47.06	124	4.69	66	5.95	24
50.37	102	2.08	31	25.98	71
36.97	153	6.56	62	21.94	66
25.50	158	19.47	116	18.27	59
52.11	99	.46	13	26.04	68
41.69	146	5.36	71	11.46	54
55.41	58	.32	10	21.90	61
46.00	134	3.91	58	10.06	59
44.73	67	5.91	37	27.61	67
49.43	107	3.04	43	32.57	70
37.10	171	3.51	34	26.88	63
41.98	151	6.34	88	4.30	26

T#55	T#56	T#57	T#58	T#59	T#60
[illegible]	[illegible]	[illegible]	[illegible]	21.02	[illegible]
[illegible]	98	[illegible]	114	3.22	[illegible]
43.60	104	[illegible]	171	[illegible]	[illegible]
45.6?	101	40.55	120	3.2?	[illegible]
35.12	10?	29.41	159	11.71	9
41.28	85	17.?5	140	12.?	7
[illegible]	94	31.78	157	5.19	55
40.74	90	34.35	155	3.75	[illegible]
28.14	79	10.24	156	21.16	90
32.54	101	24.34	15	15.57	101
45.23	96	27.?5	164	7.57	[illegible]
37.49	104	42.15	120	9.15	77
39.42	107	42.57	147	5.35	87
47.51	92	44.07	154	2.35	41
40.45	93	42.47	144	5.65	87
39.50	90	18.38	122	22.52	110
33.24	103	26.?9	149	13.75	100
39.44	104	19.13	126	19.60	102
34.07	107	24.69	175	12.57	107
39.25	103	39.78	169	5.43	64
32.95	80	9.3?	43	22.06	77
2?.66	61	25.77	52	15.94	201
46.91	90	52.22	72	.99	20
33.73	98	9.54	79	22.04	95
44.43	58	41.94	153	4.03	56
41.60	87	25.36	143	10.73	83
35.15	94	29.08	150	11.75	75
35.45	105	41.11	147	6.47	15
40.08	93	24.93	136	11.02	18
44.61	103	42.30	132	4.28	64
47.35	105	51.71	162	1.36	-21
36.66	110	39.67	149	7.48	59
34.04	100	35.69	149	10.60	95
36.69	108	23.55	132	14.24	59
36.37	96	32.75	174	9.02	[illegible]
13.68	61	5.59	52	41.52	70
32.41	99	34.81	150	12.76	110
30.99	112	31.46	170	12.53	104
25.95	93	22.44	151	22.58	115
43.05	101	44.12	144	3.61	44
36.85	105	23.62	153	9.56	79
33.15	111	37.57	158	6.57	93
49.90	80	42.51	154	2.12	32
32.56	98	28.00	141	15.32	100
45.78	99	48.46	115	2.68	42
29.52	114	37.43	162	11.89	110
46.12	89	50.57	73	2.78	25
49.65	69	44.02	133	1.23	21
30.16	69	39.35	152	3.28	39
31.60	110	40.86	137	10.55	96

T#61	T#62	T#63	T#64	T#65	T#66
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	131	[illegible]	[illegible]	[illegible]	[illegible]
41.41	131	[illegible]	[illegible]	[illegible]	[illegible]
40.46	126	[illegible]	[illegible]	[illegible]	[illegible]
34.57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27.94	95	[illegible]	[illegible]	[illegible]	[illegible]
34.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	142	97.72	[illegible]	[illegible]	[illegible]
17.46	57	53.47	[illegible]	[illegible]	[illegible]
[illegible]	99	[illegible]	[illegible]	[illegible]	[illegible]
40.20	123	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	120	[illegible]	[illegible]	[illegible]	[illegible]
34.66	110	77.25	[illegible]	[illegible]	[illegible]
46.37	139	91.59	[illegible]	[illegible]	[illegible]
29.01	99	[illegible]	[illegible]	[illegible]	[illegible]
14.35	57	[illegible]	[illegible]	[illegible]	[illegible]
30.66	95	[illegible]	211	[illegible]	[illegible]
23.05	72	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	126	76.24	[illegible]	73.23	[illegible]
39.47	111	76.75	207	[illegible]	[illegible]
15.05	62	63.91	214	[illegible]	[illegible]
22.06	72	70.04	[illegible]	[illegible]	[illegible]
30.80	[illegible]	26.29	153	[illegible]	[illegible]
15.15	53	52.09	[illegible]	[illegible]	[illegible]
41.34	121	93.23	[illegible]	31.73	[illegible]
43.80	127	36.02	174	[illegible]	[illegible]
35.72	106	82.27	194	[illegible]	[illegible]
39.39	114	78.05	191	77.35	[illegible]
47.94	124	59.41	[illegible]	[illegible]	[illegible]
54.78	[illegible]	97.08	[illegible]	75.31	[illegible]
53.6	143	95.10	167	97.77	[illegible]
39.19	114	77.49	190	[illegible]	[illegible]
27.97	95	72.36	[illegible]	[illegible]	[illegible]
24.46	62	64.69	[illegible]	[illegible]	[illegible]
39.87	122	87.69	210	[illegible]	[illegible]
12.49	45	43.51	[illegible]	[illegible]	[illegible]
29.74	105	79.08	[illegible]	33.10	[illegible]
23.92	53	63.15	194	[illegible]	[illegible]
19.67	72	65.39	216	[illegible]	[illegible]
54.11	141	84.60	[illegible]	69.50	[illegible]
43.94	131	79.69	[illegible]	94.16	[illegible]
26.50	91	59.21	210	60.59	[illegible]
59.66	136	101.04	209	53.07	[illegible]
30.69	91	74.39	173	94.62	[illegible]
58.95	126	95.79	210	59.69	[illegible]
30.64	103	70.38	[illegible]	[illegible]	173
51.65	127	88.75	223	63.43	[illegible]
50.37	127	92.15	[illegible]	95.30	[illegible]
47.04	122	87.99	[illegible]	93.45	[illegible]
22.05	77	67.53	185	[illegible]	[illegible]
			237	[illegible]	[illegible]

T#67	T#68	T#69	T#70	T#71	T#72
[illegible]	[illegible]	129.42	[illegible]	[illegible]	[illegible]
9.20	[illegible]	135.56	[illegible]	[illegible]	[illegible]
10.36	[illegible]	247.09	[illegible]	451.75	[illegible]
5.53	182	151.03	[illegible]	[illegible]	[illegible]
39.43	238	212.04	559	[illegible]	[illegible]
25.17	[illegible]	125.61	347	384.07	[illegible]
26.17	157	151.30	[illegible]	374.19	[illegible]
4.37	95	266.62	394	451.91	[illegible]
42.54	196	111.39	374	389.19	416
33.14	207	138.96	429	374.53	[illegible]
11.75	151	196.75	570	412.96	[illegible]
9.99	95	155.44	509	357.35	[illegible]
15.07	151	225.22	513	[illegible]	[illegible]
9.93	95	250.86	534	385.55	771
17.50	112	112.55	394	350.74	[illegible]
39.76	215	102.66	591	399.23	754
17.32	159	130.58	[illegible]	[illegible]	957
37.35	194	156.01	406	359.33	531
14.52	144	259.79	529	421.60	71
13.42	147	256.40	653	421.61	917
40.59	197	100.87	349	392.04	957
22.94	319	113.90	392	335.03	1014
2.26	40	260.02	545	427.61	[illegible]
41.99	211	163.02	479	404.37	741
5.54	90	151.81	485	359.78	925
14.34	113	250.81	613	402.33	733
14.16	133	216.09	597	419.91	876
10.36	122	221.59	577	371.77	985
12.27	106	244.62	633	419.93	755
4.49	72	339.53	693	465.36	834
1.96	37	235.11	526	432.81	[illegible]
11.42	126	206.97	543	350.03	[illegible]
15.90	150	146.43	477	333.30	[illegible]
35.66	201	153.53	470	326.52	[illegible]
10.66	116	152.83	476	355.03	[illegible]
57.45	165	98.84	331	234.75	[illegible]
15.14	150	109.86	371	31 .75	[illegible]
24.11	203	124.65	405	301.56	[illegible]
27.27	161	139.49	463	325.45	[illegible]
5.69	75	285.35	544	413.57	[illegible]
16.21	141	197.65	545	361.26	[illegible]
25.14	216	124.89	368	255.81	951
2.60	45	248.45	634	450.33	735
20.68	171	148.12	449	350.32	932
3.00	52	168.19	566	396.14	915
15.80	160	116.29	373	245.41	[illegible]
9.09	52	177.23	480	357.95	[illegible]
4.27	64	195.15	551	379.92	[illegible]
11.79	123	259.68	663	401.47	721
16.69	164	121.54	395	324.51	735

T#73	T#74	T#75	T#76
[illegible]	[illegible]	[illegible]	[illegible]
215.15	1277	126.	[illegible]
319.	1251	35.76	561
319.10	1453	71.23	[illegible]
335.57	1351	59.74	[illegible]
351.75	1350	127.57	541
127.59	1021	111.74	737
437.57	1120	19.35	[illegible]
334.30	1367	294.70	[illegible]
252.03	1432	139.33	411
323.50	1517	47.65	531
377.00	1303	60.56	503
345.57	1432	44.34	513
332.40	1350	27.37	529
337.71	1304	79.52	752
322.21	1032	67.31	465
337.57	1431	55.69	575
290.22	1567	56.15	552
402.35	1345	23.92	561
435.99	1164	14.92	504
241.32	1215	141.92	553
402.19	1322	55.77	722
411.40	1212	21.12	320
262.55	1267	59.79	563
377.41	1336	55.94	654
216.24	1266	67.36	519
426.29	1109	21.25	333
375.51	1327	35.43	564
346.73	1413	34.56	414
453.69	679	7.71	142
463.64	933	12.97	242
330.49	909	55.20	552
340.46	1005	78.70	745
219.03	1247	115.60	728
313.24	1497	65.71	655
220.75	1157	190.57	570
345.20	1307	96.09	503
231.01	1331	114.39	573
361.60	1421	73.83	796
439.47	1053	15.31	264
237.60	1433	38.69	589
197.25	1292	164.73	1001
445.49	1059	15.05	241
333.27	1433	76.52	721
395.79	1177	43.76	491
251.70	1114	171.64	797
274.62	1126	97.35	619
373.23	1124	60.24	512
325.63	1494	49.25	499
[illegible]	1402	114.71	[illegible]

APPENDIX C

ANOVA FOR TEST NOS. 1 THROUGH 76

APPENDIX C

ANOVA for Test Nos. 1 through 76

F significant @: .005 - 8.695 .01 - 7.201 .025 - 5.369 .05 - 4.052 .10 - 2.815 .25 - 1.356

Degrees of Freedom: Among Columns 1 Error(within) 48 Total 49 Grp 1-High Grp 2-Low

		Std. Dev.		Mean		Sum of Squares			Mean Squares		
No	Title	Grp 1	Grp 2	Grp 1	Grp 2	AC	EW	T	AC	EW	F
1	Gr Pt Av (QPR)	.1	.1	3.7	2.2	30.1	.6	30.6	30.1	.0	2554.9
2	Apt-Verbal	75.4	48.0	634.3	566.5	57460.5	199676.0	257136.0	57460.5	4159.9	13.8
3	Apt-Math	47.4	67.4	697.6	633.3	51584.7	169721.0	221306.0	51584.7	3535.9	14.6
4	Ach-Eng Comp	72.7	61.0	611.1	556.5	37210.0	224808.0	262018.0	37210.0	4683.5	7.9
5	Ach-Math	58.0	54.9	727.2	620.0	143755.0	159489.0	303244.0	143755.0	3322.7	43.3
6	Rank in Class	96.4	78.2	650.0	508.1	251766.0	385470.0	637236.0	251766.0	8030.6	31.4
7	Recom Score	31.3	105.3	760.8	677.0	87780.5	301612.0	389392.0	87780.5	6283.6	14.0
8	Extra Cur Activ	104.5	150.6	479.8	506.6	8978.0	839810.0	848788.0	8978.0	17496.0	.5
9	Whole-Man-Mult	3919.0	5621.8	63258.0	57045.4	482447000.0	1174060000.0	1656510000.0	482447000.0	2445968.0	19.7
10	CWF 2	3.2	2.9	3.4	3.6	.2	470.3	470.5	.2	9.8	.0
11	Hay Fever	3.7	3.7	13.4	13.4	0.0	672.0	672.0	0.0	14.0	0.0
12	L or R Handed	3.7	3.2	13.4	13.8	2.0	600.0	602.0	2.0	12.5	.2
13	Rest-Theta-Time	29.5	40.6	103.6	87.5	3238.8	62961.0	66199.8	3238.8	1311.7	2.5
14	Rest-Theta-Count	35.2	67.6	211.6	185.5	8528.2	145258.0	153786.0	8528.2	3026.2	2.8
15	Rest-Alpha-Time	13.9	33.3	160.2	141.3	4454.0	32482.9	36936.9	4454.0	676.7	6.6
16	Rest-Alpha-Count	54.7	96.4	120.1	176.9	40334.8	307160.0	347544.0	40384.8	6399.2	6.3
17	Rest-Beta-Time	21.5	17.6	58.6	47.5	1520.8	19262.2	20783.0	1520.8	401.3	3.8
18	Rest-Beta-Count	84.4	87.4	365.2	325.6	19602.0	369342.0	388944.0	19602.0	7694.6	2.5
19	Rest-S/L-Time	12.1	30.5	12.2	26.5	2534.9	26885.8	29420.6	2534.9	560.1	4.5
20	Rest-S/L-Count	51.8	91.3	83.5	132.3	29816.8	275646.0	305462.0	29816.8	5742.6	5.2
21	Math-Theta-Time	21.8	20.4	56.0	57.9	44.2	22317.6	22361.8	44.2	464.9	.1
22	Math-Theta-Count	44.8	36.7	165.0	168.4	141.1	83733.8	83874.9	141.1	1744.5	.1
23	Math-Alpha-Time	17.6	20.3	121.5	120.8	5.5	18008.1	18013.5	5.5	375.2	.0
24	Math-Alpha-Count	28.7	30.1	300.6	303.3	89.8	43227.1	43316.8	89.8	900.6	.1

F significant @: .005 - 8.695 .01 - 7.201 .025 - 5.369 .05 - 4.052 .10 - 2.815 .25 - 1.356

Degrees of Freedom: Among Columns 1 Error(within) 48 Total 49 Grp 1-High Grp 2-Low

		Std. Dev.		Mean		Sum of Squares			Mean Squares		
No	Title	Grp 1	Grp 2	Grp 1	Grp 2	AC	EW	T	AC	EW	F
25	Math-Beta-Time	27.9	30.1	117.3	119.0	36.9	42230.1	42267.0	36.9	879.8	.0
26	Math-Beta-Count	66.5	82.5	430.0	420.2	1220.1	280844.0	282064.0	1220.1	5850.9	.2
27	Math-S/L-Time	14.7	17.1	22.5	22.3	.2	12673.8	12674.1	.2	264.0	.0
28	Math-S/L-Count	89.0	93.7	210.4	205.5	196.0	417506.0	417702.0	196.0	8698.1	.0
29	Concep-Theta-Time	17.9	19.2	69.5	73.9	242.2	17208.1	17450.2	242.2	358.5	.7
30	Concep-Theta-Count	23.9	25.8	190.6	195.3	269.1	30918.8	31187.9	269.1	644.1	.4
31	Concep-Alpha-Time	12.1	19.4	127.2	124.4	101.2	13046.6	13147.8	101.2	271.8	.4
32	Concep-Alpha-Count	22.3	28.4	305.9	307.1	19.3	32579.2	32598.5	19.3	678.7	.0
33	Concep-Beta-Time	25.4	31.6	119.3	120.0	7.1	41125.8	41132.9	7.1	856.8	.0
34	Concep-Beta-Count	61.8	79.3	449.6	412.5	17149.5	252564.0	269714.0	17149.5	5261.8	3.3
35	Concep-S/L-Time	9.4	15.9	17.1	18.8	36.0	8500.1	8536.1	36.0	177.1	.2
36	Concep-S/L-Count	62.2	82.3	183.4	174.6	976.8	266146.0	267123.0	976.8	5544.7	.2
37	CumNum-Theta-Time	23.6	31.1	52.2	56.4	221.0	38117.4	38338.4	221.0	794.1	.3
38	CumNum-Theta-Count	47.6	62.2	153.1	156.4	134.5	153312.0	153446.0	134.5	3194.0	.0
39	CumNum-Alpha-Time	23.6	32.3	125.5	117.5	791.2	40102.5	40893.7	791.2	835.5	.9
40	CumNum-Alpha-Count	59.7	78.8	255.8	263.0	655.2	244051.0	244706.0	655.2	5084.4	.1
41	CumNum-Beta-Time	34.6	34.1	89.5	91.1	31.7	59096.3	59128.0	31.7	1231.2	.0
42	CumNum-Beta-Count	93.4	78.7	427.4	427.3	.3	373019.0	373019.0	.3	7771.2	.0
43	CumNum-S/L-Time	20.6	27.3	29.8	34.2	244.8	29286.1	29531.0	244.8	610.1	.4
44	CumNum-S/L-Count	75.2	106.1	207.6	220.0	1922.0	422804.0	424726.0	1922.0	8808.4	.2
45	Color-Theta-Time	6.9	8.6	18.4	21.8	137.8	3019.6	3157.4	137.8	62.9	2.2
46	Color-Theta-Count	13.5	13.1	55.2	59.3	204.0	8839.6	9043.6	204.0	184.2	1.1
47	Color-Alpha-Time	7.0	6.9	39.0	41.4	73.3	2406.8	2480.1	73.3	50.1	1.5
48	Color-Alpha-Count	10.1	14.3	101.8	101.5	1.3	7634.2	7635.5	1.3	159.0	.0
49	Color-Beta-Time	10.9	9.2	38.5	44.1	396.0	5107.2	5503.2	396.0	106.4	3.7
50	Color-Beta-Count	32.7	31.4	139.4	120.2	4588.8	51344.6	55933.4	4588.8	1069.7	4.3
51	Color-S/L-Time	6.4	5.7	8.1	5.5	84.2	1810.5	1894.7	84.2	37.7	2.2
52	Color-S/L-Count	32.4	32.2	71.4	55.2	3280.5	52235.1	55515.6	3280.5	1088.2	3.0
53	Syringe-Theta-Time	6.6	7.3	15.9	17.4	26.3	2436.9	2463.2	26.3	50.8	.5

F significant @: .005 - 8.695 .01 - 7.201 .025 - 5.369 .05 - 4.052 .10 - 2.815 .25 - 1.356

Degrees of Freedom: Among Columns 1 Error(within) 48 Total 49 Grp 1-High Grp 2-Low

		Std. Dev.		Mean		Sum of Squares			Mean Squares		
No	Title	Grp 1	Grp 2	Grp 1	Grp 2	AC	EW	T	AC	EW	F
54	Syringe-Theta-Count	16.9	15.5	48.2	50.6	72.0	13131.5	13203.5	72.0	273.6	.3
55	Syringe-Alpha-Time	7.0	8.3	37.7	37.9	.3	2958.0	2958.3	.3	61.6	.0
56	Syringe-Alpha-Count	11.0	13.8	93.9	96.5	87.1	7808.9	7896.0	87.1	162.7	.5
57	Syringe-Beta-Time	11.9	10.3	31.3	35.1	180.9	6224.6	6405.5	180.9	129.7	1.4
58	Syringe-Beta-Count	33.3	26.8	132.7	142.4	1161.6	45708.8	46870.4	1161.6	952.3	1.2
59	Syringe-S/L-Time	7.8	8.2	11.4	10.0	23.2	3206.4	3229.6	23.2	66.8	.3
60	Syringe-S/L-Count	43.1	29.1	82.3	73.2	1039.7	67639.4	68679.1	1039.7	1409.2	.7
61	Tot Str-Theta-Time	12.4	13.7	34.4	39.1	283.6	8586.3	8869.9	283.6	178.9	1.6
62	Tot Str-Theta-Count	27.9	24.5	103.4	109.8	518.4	34465.4	34983.8	518.4	718.0	.7
63	Tot Str-Alpha-Time	12.6	13.5	76.7	79.3	83.6	8508.3	8591.9	83.6	177.3	.5
64	Tot Str-Alpha-Count	17.2	17.6	195.7	198.0	67.3	15097.4	15164.7	67.3	314.5	.2
65	Tot Str-Beta-Time	20.9	17.3	69.8	79.2	1109.1	18334.6	19443.7	1109.1	382.0	2.9
66	Tot Str-Beta-Count	49.8	43.9	273.4	262.6	1468.8	110282.0	111751.0	1468.8	2297.5	.6
67	Tot Str-S/L-Time	12.7	11.9	19.5	15.6	195.6	7595.4	7791.0	195.6	158.2	1.2
68	Tot Str-S/L-Count	64.8	52.6	157.7	128.4	10745.8	174103.0	184849.0	10745.8	3627.2	3.0
69	TotProb-Theta-Time	53.5	60.9	177.6	188.1	1374.5	164299.0	165673.0	1374.5	3422.9	.4
70	TotProb-Theta-Count	99.8	105.5	508.7	520.0	1590.5	527187.0	528777.0	1590.5	10983.1	.1
71	TotProb-Alpha-Time	44.7	60.1	374.2	362.7	1644.4	140397.0	142041.0	1644.4	2924.9	.6
72	TotProb-Alpha-Count	82.0	93.6	862.2	873.4	1557.0	387270.0	388827.0	1557.0	8068.1	.2
73	TotProb-Beta-Time	77.3	78.7	326.1	330.1	206.6	304297.0	304504.0	206.6	6339.5	.0
74	TotProb-Beta-Count	142.3	183.2	1307.1	1221.3	92020.0	1344415.0	1436435.0	92020.0	28008.6	3.3
75	TotProb-S/L-Time	57.6	48.8	75.6	75.4	.3	142658.0	142658.0	.3	2972.0	.0
76	TotProb-S/L-Count	188.9	227.7	601.4	601.0	2.0	2188899.0	2188901.0	2.0	45602.1	.0

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